

White Paper

Report of the Verification, Validation & Certification (VV&C) Tiger Team

4 June 1998

VERIFICATION, VALIDATION & CERTIFICATION (VV&C) TIGER TEAM

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Executive Summary

DoD Directive 5000.59 mandates that each DoD Component establish Verification, Validation and Accreditation (VV&A) policies, procedures, and guidelines for models, simulations, and their associated data. Models and Simulations (M&S) require data to define the scenario, environment, doctrine, weapon system performance, and other factors. In an environment that relies heavily on the credibility of M&S results, quality data are as important as the performance of the models and simulations themselves. However, unlike Verification, Validation (V&V) and Accreditation, which has been addressed in detail, data Verification, Validation and Certification (VV&C) is still not at a stage of general understanding and practical implementation. A summary of relevant issues and efforts to date, and recommendations for moving forward as a community are needed.

A VV&C Tiger Team was formed in late 1997 under the auspices of the VV&A Technical Working Group. The team was composed of representatives from the Army, Navy, Air Force, Office Secretary of Defense (OSD), and the Modeling and Simulation Executive Agents (MSEA).

The objective was to develop a common technical foundation for data user V&V and Certification to enable each DoD Component to prepare tailored policies and implementation action plans. The team focused on:

- assessing the current state of DoD VV&C products
- leveraging relevant VV&C activities of the M&S community at large
- converting these activities into specific products
 - generic user template for VV&C
 - data user integrated VV&A/VV&C model
 - suggested topics for inclusion in the rewrite of the *VV&A Recommended Practices Guide*
- ascertaining remaining activities needed to reach this desired technical end state
- making recommendations to the VV&A Technical Working Group.

There is a distinction between data V&V activities performed by the producer and by the user. Producer data V&V equates to Data Quality as defined by the DoD 8320 series. User data V&V activities are an integral part of M&S V&V and Accreditation. User data certification is implicit in the acceptance of the data for accreditation of the M&S. A relationship clearly exists between producer data quality activities and user data V&V requirements throughout the M&S life cycle. The data user applies the data quality metadata to support V&V and Accreditation.

Based on this conclusion, the primary recommendation of the VV&C Tiger Team is to articulate, document and promulgate a new M&S data paradigm which distinguishes between producer data quality and user data V&V and also integrates user data V&V into M&S V&V and Accreditation.

1. Introduction

a. Background

DoD Directive 5000.59 mandates that each DoD Component establish Verification, Validation and Accreditation (VV&A) policies, procedures, and guidelines for models, simulations, and their associated data. Models and Simulations (M&S) require data to define the scenario, environment, doctrine, weapon system performance, and other factors. In an environment that relies heavily on the credibility of M&S results, quality data are as important as the performance of the models and simulations themselves. However, unlike Verification, Validation (V&V) and Accreditation, which has been addressed in detail, data Verification, Validation and Certification (VV&C) is still not at a stage of general understanding and practical implementation. A summary of relevant issues and efforts to date, and recommendations for moving forward as a community are needed.

b. Definitions

The established DoD definitions for VV&C and its component parts (ref. DoDD 5000.59-P) are presented here:

Data Verification – Data producer verification is the use of techniques and procedures to ensure that data meets constraints defined by data standards and business rules derived from process and data modeling. Data user verification is the use of techniques and procedures to ensure that data meets user specified constraints defined by data standards and business rules derived from process and data modeling, and that data are transformed and formatted properly.

Data Validation – The documented assessment of data by subject area experts and its comparison to known or best-estimate values. Data user validation is that documented assessment of data as appropriate for use in an intended model. Data producer validation is that documented assessment within stated criteria and assumptions

Data Certification – The determination that data have been verified and validated. Data user certification is the determination by the application sponsor or designated agent that data have been verified and validated as appropriate for the specific M&S usage. Data producer certification is the determination by the data producer that data have been verified and validated against documented standards or criteria.

2. The Tiger Team

a. Formation

A VV&C Tiger Team was formed in December 1997 under the auspices of the VV&A Technical Working Group (TWG). The Tiger Team was to complete its task within four months of the first meeting of the full membership, convened on 8 January 1998. The team was composed of representatives from the Army, Navy, Air Force, Office Secretary of Defense (OSD), and the Modeling and Simulation Executive Agents (MSEA). A list of Tiger Team members is provided in Appendix A. The team restricted itself to considering only computer-based M&S, although some of its results may be applicable to other forms of M&S. It was

understood that the Tiger Team had no authority to state policy or implement its recommendations.

The purpose of the VV&C Tiger Team was to assist in identifying the key issues within the DoD Modeling and Simulation (M&S) community pertaining to the V&V and Certification of user data. The team was to examine present processes, guidelines and practices used in the conduct of V&V and Certification activities. It would then assess what had been done to date to encourage V&V and Certification throughout the DoD M&S community, consider what remained to be done, and recommend actions to further that outcome. The Tiger Team was then to provide a summary of its conclusions and recommendations to the VV&A TWG. The recommendations would be passed to the DoD Modeling and Simulation Working Group (MSWG) for action. The conclusions and recommendations were to be non-binding on the TWG, MSWG or Tiger Team participating agencies.

b. Objectives

The objective of the Tiger Team was to develop a common technical foundation for data user V&V and Certification to enable each DoD Component to prepare tailored policies and implementation action plans. The Tiger Team sought to:

- assess the current state of DoD VV&C products
- leverage relevant VV&C activities of the M&S community at large
- convert these activities into specific products
 - generic user template for VV&C
 - data user integrated VV&A/VV&C model
 - suggested topics for inclusion in the rewrite of the *VV&A Recommended Practices Guide*
- ascertain what remaining activities are needed to reach the desired technical end state and make appropriate recommendations.

The Tiger Team was to generate this White Paper and an associated annotated briefing of its products, conclusions and recommendations. The team was to present these results to the VV&A TWG prior to its release to the M&S community at large. The formal Terms of Reference (TOR) for the Tiger Team is provided in Appendix B.

c. Process

The Tiger Team formed four sub-groups to work individual elements of the objectives. The members of these sub-groups are listed in Appendix A. These sub-groups and associated tasks were:

- Leverage – exploit the current state of VV&C resources, information and knowledge
- Template – create a user-driven template of data quality information
- Model – develop a data user integrated VV&A/VV&C model
- RPG – suggested topics for the rewrite of *VV&A Recommended Practices Guide* (RPG)

The Tiger Team's approach to the work made it possible for continuous review and consensus building. The subgroups met independently, but with a series of face-to-face and teleconference meetings of the entire Tiger Team. The team meetings sought to create synergy between subgroup efforts, avoid duplication of effort, and resolve issues. Information exchange and products-in-work were made available on a dedicated website, and ready communication between team members was facilitated via an electronic mail reflector. Regular status updates on the Tiger Team progress were made to the VV&A TWG by the team's Chairman. The team's products, conclusions and recommendations were restricted to only team members throughout their development.

3. Products

a. VV&C Bibliography, Tools, and Pilot Project Summaries

The Leverage sub-group produced a bibliography of existing literature, a listing of data V&V tools, and a compilation of lessons learned from relevant efforts and pilot projects. This information provided a foundation for the other sub-group activities. The products presented in Appendix C will allow persons new to the subject of data V&V to gain valuable insight and identify essential tools.

b. Data Quality Metadata Template

The Data Quality Metadata Template shown in Appendix D is designed to guide data users in identifying the type of producer-generated Data Quality (DQ) information that will support V&V and Accreditation activities. The template presents a comprehensive list of metadata fields which, when filled out by the data producer, should improve the M&S users' understanding of the quality of the data. It will also provide significant information to support the users' model and simulation V&V and Accreditation activities. The template specifies three data levels, three descriptor categories, and three priority rankings. The template provides a guide for producers to tailor their DQ metadata collection and for users to judge the adequacy of data for their specific needs. A data dictionary is embedded in the template to define each metadata item.

c. M&S Life Cycle Process Model

The existing M&S Life Cycle Process Model, originally created to support development of the *DoD VV&A Recommended Practices Guide*, was updated to incorporate data aspects. This provided insight into the roles and responsibilities associated with user data verification and validation. The DoD Components and other organizations may wish to use the Model to assist in drafting guidance, creating necessary training, or supporting other related efforts. The Model is presented in Appendix E as a set of IDEF0 diagrams and supporting definitions and guidepost charts.

d. Recommended VV&C Content for the VV&A RPG and for VV&A Policy/Guidance

The RPG sub-group was composed of the Component and sub-group leads. The RPG sub-

group's recommendations were based on the products and findings produced by the other sub-groups. The sub-group developed two sets of recommendations; one is applicable to general VV&A policy and guidance documents (see Appendix F), and the other is specific to the *DoD VV&A Recommended Practices Guide* (see Appendix G). The former supports the tailoring of policies and implementation action plans by each Component. The latter supports the ongoing revisions of the *VV&A RPG*.

4. Conclusions and Recommendations

Conclusions:

- A. There is a distinction between data V&V activities performed by the producer and by the user. Producer data V&V equates to Data Quality as defined by the DoD 8320 series. User data V&V activities are an integral part of M&S V&V and Accreditation. User data certification is implicit in the acceptance of the data for accreditation of the M&S. A relationship clearly exists between producer data quality activities and user data V&V requirements throughout the M&S life cycle. The data user applies the data quality metadata to support V&V and Accreditation.
- B. Based on the review of existing processes and the desired end state the following gaps have been identified:
 - lack of consistency in the application of user data V&V activities
 - disconnect between Producer DQ Products and user data V&V requirements
 - no central library for user data V&V information
 - lack of integration of user data V&V with the M&S V&V and Accreditation

Recommendations:

- A. Articulate, document and promulgate a new M&S data paradigm which:
 - distinguishes between producer data quality and user data V&V
 - integrates user data V&V into M&S V&V and Accreditation.
- B. Incorporate the following into guidance documents:
 - the new paradigm, described above, and DQ Metadata Template (Appendix D) into the revisions of DoDI 5000.61 and VV&A RPG, the draft M&S Data Quality Guidelines, and related Component implementing documents
 - revised M&S Life-Cycle Process model (Appendix E) into the VV&A RPG
 - recommended V&V and Certification Content for the VV&A RPG (Appendix G) and General Recommendations for Changes to V&V and Accreditation Policy/Guidance (Appendix F).
- C. Review the current VV&A TWG charter to ensure that issues related to user data V&V are addressed. Review membership in light of the new paradigm.
- D. Eliminate the use of the conglomerate term VV&C and emphasize the activities associated

with data verification and validation.

- E. Solicit feedback on the new paradigm addressed in the conclusions and the revised M&S Life-Cycle Process Model (Appendix E) from new development efforts (e.g., JWARS, JSIMS), one or more potential pilot projects (e.g, an Architecture Management Group [AMG] identified High Level Architecture [HLA] project), and application of legacy M&S at various levels of abstraction and purpose.
- F. VV&A TWG sponsor presentations derived from the White Paper and Tiger Team products.
- G. Disseminate information regarding the new paradigm to appropriate data programs within the DoD M&S community.
- H. The VV&A TWG forward the DQ Metadata Template to the Authoritative Data Sources Working Group for consideration in future data calls.
- I. Provide public access to a library that includes the bibliography and tool list shown in Appendix C. Establish a custodian for the configuration management of this library. Solicit DoD Components to add to the library.

Appendix A

VV&C Tiger Team Membership

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Model Sub-Group

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RPG Sub-Group

Youngblood (*Chair*), De La Cruz, Kilikauskas, Kim, McGlynn, Norton, Senko, Stanley, Weatherly

Template Sub-Group

Bob Senko (*Chair*), Black, Brewer, De La Cruz, Finsod, Fragapane, Lambert, Lucas, Tatsumi

Appendix B

Terms of Reference

Verification, Validation & Certification (VV&C) Tiger Team

This Terms of Reference (TOR) establishes the Verification, Validation and Certification Tiger Team.

PURPOSE

The purpose of this Verification, Validation and Certification (VV&C) Tiger Team is to assist in identifying the key issues within the DoD Modeling and Simulation (M&S) community pertaining to the VV&C of data. The Tiger Team's efforts shall focus on data user VV&C and its association with Verification, Validation, and Accreditation (VV&A). This includes an examination of present processes, guidelines and practices used in the conduct of VV&C activities. The Tiger Team will assess what has been done to date to encourage VV&C throughout the DoD M&S community, consider what remains to be done, and recommend actions to further this outcome. The Tiger Team will provide a summary of their findings and recommendations to the VV&A Technical Working Group (TWG). The recommendations will then be passed to the DoD Modeling and Simulation Working Group (MSWG) for any further action, and are non-binding on the MSWG or Tiger Team participating agencies.

AUTHORITY

This VV&C Tiger Team exists under the auspices of the VV&A TWG, which is in turn sponsored by the MSWG. The Tiger Team has no authority to state policy or implement its recommendations.

BACKGROUND

DoDD 5000.59 mandates that each DoD Component establish VV&A/C policies, procedures, and guidelines for models, simulations, and their associated data. M&S applications require data to define the scenario, environment, doctrine, weapon system performance, etc. Obtaining these data is process intensive and very dependent on the user's knowledge and access to available data sources. Additionally, data are typically developed for a specific requirement(s) with little or no reuse intended. Current *ad hoc* methods to acquire, access, and VV&C this data may be costly, inefficient, and often results in questionable credibility of the data. In an environment that stresses the criticality of M&S results, quality data is as important as the performance of the models and simulations themselves. However, unlike VV&A, which has been addressed in detail, VV&C is still not at a stage of general understanding and practical implementation. A summary of relevant issues, efforts to date, and recommendations for moving forward as a community are needed.

DURATION & PRODUCTS

The Tiger Team is to complete its task within four months of the first meeting of the full membership. The anticipated level of effort will involve at least six interactive group meetings. These meetings will be conducted using videoteleconference, reflector, or teleconference methods as appropriate. Face-to-face meetings will be held to a minimum required to resolve key/contentious issues. Each meeting may require several days pre- and post-meeting preparation time.

The Tiger Team will produce a White Paper and associated annotated briefing of its findings and recommendations. This product will include a user-driven template of data quality processes for the data user and a data user integrated VV&A/VV&C model. The team will present these products to the VV&A TWG prior to its release to the M&S community at large. Length and depth of paper will be consonant with available resources and level of effort.

Objective

The objective of the team is to develop a common technical foundation for data user VV&C to enable each DoD Component to prepare tailored policies and implementation action plans. The Tiger Team will:

- Assess the current state of DoD VV&C products
- Leverage relevant VV&C activities of the M&S community at large
- Convert these activities into specific products
 - Generic user template for VV&C
 - Data user integrated VV&A/VV&C model
 - Suggest topics for inclusion in the rewrite of the *VV&A Recommended Practices Guide*
- Ascertain what remaining activities are needed to reach this desired technical end state - at the conclusion of Tiger Team activities - and make appropriate recommendations

KEY MILESTONES

Anticipated meeting dates are as follows:

Kick-off meeting: 8 Jan 98

Final product meeting: 21 May 98

Anticipated brief to VV&A TWG: 29 May 98

Anticipated brief to MSWG: *TBD*

PARTICIPATION

The membership of the VV&C Tiger Team will be drawn from the DoD Components. It will be composed of a small group willing to work intensely for a brief period on very specific end products. The team is made up of representatives focused on data user VV&C and its association with VV&A.

Appendix C

VV&C Bibliography, Tools, and Pilot Project Summaries

The Tiger Team explored the existing literature on V&V and Certification, examined extant tools for performing data V&V and Certification, and looked at pilot programs and other past experience in performing V&V and Certification. The common database data checking functions and statistical analysis packages, while important, were not the sort of tools addressed in this effort. All this then lent insight for drawing overall conclusions on which recommendations could be formulated.

Specific References

1. Data Verification, Validation and Certification (VV&C) for Distributed Simulations, Susan D. Solick, TRAC Operations Analysis Center, solicks@trac.army.mil, <http://ftp.sc.ist.ucf.edu/SISO/dis/workshop/14th/ABSTRACT/128.txt>.
2. Jeff Rothenberg, Walter Stanley, George Hanna, and Mark Ralston, Rand Project Memorandum PM-710-DMSO, August 1997.
Comments: This report offers an outstanding theoretical foundation for V&V and Certification. It includes a VV&C process model and considerations for structuring individual V&V and Certification efforts with different kinds of data. It also provides a guide for planning both producer and user V&V and Certification plans.
3. "Data Verification, Validation, and Certification to Improve the Quality of Data Used in Modeling," Jeff Rothenberg & Iris Kameny, Proceedings of the 1994 Summer Computer Simulation Conference (SCSC'94), La Jolla, California, July 18-20 1994, p. 639-644, Society of Computer Simulations (SCS), ISBN 1-56555-029-3, 1994.
Comments: This paper presents a three-tiered solution to the problem of data quality, involving the use of metadata, explicit V&V and Certification, and controlling the processes that affect data.
4. "A Discussion of Data Quality for Verification, Validation, and Certification (VV&C) of Data to be Used in Modeling," Jeff Rothenberg, Rand Project Memorandum PM-709-DMSO, August 1997.
Comments: This is an essential guide to DQ and V&V and Certification. Includes considerations for metadata used in judging data quality and supporting V&V and Certification.
5. DIS Data VV&C and its Relationship to the DIS Exercise Life Cycle, DIS VV&A, and the Generic VV&C Process, Susan D. Solick, TRAC Operations Analysis Center, solicks@trac.army.mil, (913) 684-9122. DRAFT
Comments: This is a very good outline of the general V&V and Certification process.

6. Interaction Between the Data VV&C and Model V&V Activities of the DIS VV&A Process Model, 12-95-033, Susan Solick, TRAC Operations Analysis Center, Simulation and Data Standards Verification and Validation, Fort Leavenworth, Kansas.

Comments: This paper examines DIS data V&V and Certification as it evolved within the DIS V&V and Accreditation process model and discusses the interdependence of data V&V and Certification and DIS V&V activities.

7. Pedigree Database Process Road to VV&C, Nancy Clements & Larry Beasley, Aeronautical Systems Center, 20 November 1997, (937) 255-4343, DSN 785-3797.

Comments: This paper provides a clear summary of this V&V and Certification tool (described below) and the process for implementing it.

8. "Verification, Validation and Certification of DIS Exercise Data," Jeff Rothenberg, Proceedings of the 14th Workshop on Standards for the Interoperability of Distributed Simulation, (DIS-14), paper ID: 96-14-120.

General References

9. DoD Guidelines on Data Quality Management, <http://ssed1.ncr.disa.mil/srp/datadmn/dqpaper.html>.
 10. Data Administration Procedures, DoD 8320.1-M, OASD/C3I, DTIC, Alexandria Virginia, 1994.
 11. Data Quality Assurance Procedures, DoD 8320.1-M-3, OASD/C3I, DTIC, Alexandria, Virginia. (in draft February 1994)
 12. Data Quality Control and Editing, Joseph I. Naus, Marcel Dekker, New York, 1975.
 13. Data Quality Control: Theory and Pragmatics, Gunar E. Liepins and V.R.R. Uppuluri, Marcel Dekker, New York, 1990.
 14. Data Quality Management and Technology, Thomas C. Redman, Bantam Books, ISBN 0-553-09149-2.
 15. Data Quality for the Information Age, Thomas C. Redman, Artech House, Norwood, Maine, 1996, ISBN 0-89006-8836.
 16. Data Warehouse Quality, Duane Hufford, <http://www.data-warehouse.com/resource/articles/hoffor7.htm>.
- Comments:* This touches on V&V and Certification for Decision Support Systems (DSS) for risk mitigation, and is a good theoretical overview.
17. "Metadata to Support Data Quality and Longevity," Jeff Rothenberg, 1996, jeff@rand.org or http://www.computer.org/conferen/meta96/rothenberg_paper/ieee.data-quality.html.

Comments: This document presents a good theoretical foundation for V&V and Certification.

18. Modeling and Simulation (M&S) Data Administration Strategic Plan (DASP), DMSO, April 1995.

19. Modeling and Simulation (M&S) Master Plan, DoD, 5000.59-P, October 1995.

Comments: Basic guidance underlying the need for DoD V&V and Certification processes.

20. On Validation Approach in Data Production, Jacob Lee & Richard Y. Wang, TDQM Research Program, MIT, 1993.

21. A Process for Data Quality, Henry B. Kon, Jacob Lee & Richard Y. Wang, TDQM Research Program, MIT, March 1993.

22. Verification, Validation and Accreditation (VV&A), Air Force Instruction 16-1001, 1 June 1996, http://xoc.hq.af.mil/kb/docs/vva_afi.html.

Comments: This is the USAF V&V and Accreditation guidance, answering to DoD 5000.59, which also supports V&V and Certification.

23. Verification, Validation, and Accreditation of Army Models and Simulations, United States Army, Pamphlet 5-11, 15 October 1993.

Comments: This document is currently being updated to include general guidance on data management and V&V and Certification (Chapter 6.0).

24. Verification, Validation, and Accreditation (VV&A) of Models and Simulations, SECNAV Instruction 5200, draft December 1995.

Comments: This is the basic Navy V&V and Accreditation guidance that also impacts V&V and Certification.

25. Verification, Validation and Accreditation (VV&A) Recommended Practices Guide, DMSO, November 1996.

Comments: This document is the essential reference for the integration of V&V and Certification with V&V and Accreditation.

Tools

- Data Verification Interactive Editor (DAVIE) Ken Simmons, CoTs, 813-837-4515

This tool does data verification on existing ASCII and Relational Database Management System tables. It is a government tool capable of accessing disparate data in various formats on a variety of platforms and in a variety of environments. It performs quality inspection and other DQ functions using defined rules and can be customized to a user's particular needs.

- Data Quality Engineering (DQE) LTC Mike Casas, USCENTCOM, 813-828-4230

This GOTS tool is used by the US Central Command to improve the data integrity of planning

models. This tool performs semi-automated data verification using rule-based checks for anomalies, filtering suspect data. Because there is only one user of DQE at present, its flexibility is very limited.

- QDB/Analyze Jim Lair, QDB Solutions, 703-620-6131

This is a mature and versatile COTS DQ tool supporting software using rules and other user-defined checks.

- NIMA's VV&C Criteria

The Tiger Team could learn nothing about this tool.

- Line Comments Craig Jones, BDM, (505) 998-8100

BDM Federal in Albuquerque has used the practice of inserting comment lines into the input files for such codes as Suppressor and the Simulated Warfare Environment Generator (SWEG). These comments can document the source(s) of the data, and the algorithms used to transform raw data to be appropriate for the model's input parameters or the intended use of the model and data set. BDM has guidelines for this in-line documentation practice. Such comments are essentially metadata that, as comments, are unlikely to be lost. They are also very easy to change as the data migrates and is changed further.

- MASTR (Modeling, Analysis, Simulation, and Training) "Data and Study Management System" Captain Byron Tatsumi AFSAA, (703) 697-9005

MASTR is presently used by the Air Force Studies and Analysis Agency (AFSAA) to allow analysts to manipulate M&S data input and to study results. MASTR has several dimensions. It is a database management system, attempting to automate data quality checks and data validation. It is a study management tool allowing for tracking of studies by using audit trails (audits every change to data in the central database) and a version control system. And, it allows qualitative viewing of data supporting verification and validation.

- Pedigree Database Nancy Clements, ASC/XR, (937) 255-4343

This is used by the USAF Aeronautical Systems Center to support the Needs Analysis, Requirements Analysis, Analysis of Alternatives and Capability assessments for proposed weapon systems. It provides for consistency and an audit trail for data from the source and through the hierarchy of models as it is aggregated up. It also ensures correlation of data and calibration of model methodologies with original collected data. Comprehensive documentation requirements are specified. Procedures for database certification are included.

Lessons Learned/Pilot Projects

- DMSO VV&C Task Group Case Studies 1995 (Dr. Walt Stanley, TRW, 505-998-8389)

The Task Group documented case studies of five data producer and six data user DoD organizations performing data V&V and Certification. These are listed below with the responsible organization, the principal point-of-contact, and the name of the effort.

Producer Case Studies -

NAVO (Eleanor Schroeder), Acoustic Bottom Loss, Temperature & Oceanography Database
NAIC (Ray Persing), Models of Foreign Aircraft Physical Characteristics
OPTEC (Dr. Kerry Wyant), Operational Test Data
DIA (Richard Bernstein), NGIC & ONI Examples of Intelligence Products
DMA (Dave Danko), DTED and Vector Smart Map

User Case Studies -

TRADOC/TRAC (Howard Haeker), Cost and Operational Effectiveness Analyses
TACCSF (Tony Brozena), Operator-in-the-Loop Air Defense Simulation
JTMD/AO (Kim Heard), Attack Operations Simulation Network
JWFC (Major Greg Brouillette), Integrating Simulations for Exercises and Training
OPNAV N812D4 (Robert Hartling), Programmatic & Campaign Analysis
OSD PA&E (Dr. Susan Marquis), Process JWARS Model Data

The case studies revealed definitively that data producer V&V and Certification principally revolves around data quality processes. These processes are well established, and all of the producers examined had sound DQ procedures.

- Air Force VV&C Prototype Project – Weather 1995 (Ms. Teea Kim, AF/XOC, 202-761-5340 x105)

This effort was to serve as a pilot project of V&V and Certification activities in order to gain detailed lessons learned. The project was to use the generation and dissemination of weather data as a basis for the trial. It was to leverage off the work of the DMSO VV&C Task Group, but the Task Group did not generate a product in sufficient time. Hence, the project found itself with very limited guidance, and termination of the funding further limited the outcome. The project team created a V&V and Certification database about the project's database containing quality information, references to publications, and actual error data from quality checks. These were in "FoxPro" database tables, all related to one another, and including sample reports that demonstrated how one might use the database. Although the project was hamstrung by confusion over the objectives and by funds limitations, the team clearly had very little guidance about V&V and Certification. The contents of this White Paper and the VV&A RPG, rewritten to include V&V and Certification guidance, would have been invaluable in making this effort truly productive.

- JCOS VV&C 1997 (Mr. Ed Harvey, BMH Associates, 757-857-5670)

BMH was selected to conduct Joint Countermine Operational Simulation (JCOS) V&V and Accreditation in October 1996. DMSO, looking to leverage lessons learned from the BMH JCOS effort, tasked BMH to submit recommended changes to DoD VV&A RPG based on practical experience and recommend changes to the initial draft data V&V and Certification guide developed for DMSO. In response, BMH developed a data "VV&C vignette" based on an undersea mine model. The BMH validation approach was to compare the model output to expected results where a previously defined set of "A/B" tables served as the expected result.

The BMH lessons learned included:

- Data verification is a process distinct from data validation and certification.
- Data verification is a distinct process that is separate from software V&V and Accreditation.

- Simulation developers consume verified data.
- Data validation should be easy. It is a straightforward comparison of data accuracy by designated Subject Matter Expert (SME) personnel. However, finding an SME who is “designated” to validate data is the hard part.
- The location of data used in an M&S application should be consistent.
- All data for a given M&S should be in the conceptual models (functional descriptions) on which the M&S is based.
- It is difficult, if not impossible, to validate a software model without considering data validation.
- Ask these questions:
 - How does the output of the model compare to the expected results?
 - Are the expected results accurate to begin with?
 - What is the distinction between data validation and data certification from a developer’s perspective?
- Data certification is the determination that data has been verified and validated.

BMH’s recommendations included:

- Distinguish between data validation and data certification.
- The current definition of data certification is insufficient. It should include a limitation that only validated data used with a validated model is “certified” for use with that specific model.
- Develop a data verification ‘recommended practices guide’ to be used by data producers.
- Data validation and certification is an integral part of software validation and should not be a separate process.
- Include data validation and certification in the DMSO VV&A *RPG*.

- Joint Strike Fighter (JSF) Preparation for VV&C 1998 (Ms. Michelle Kilikauskas, Naval Air Warfare Center Weapons Division, 760-927-1260, DSN 469-1260)

The Joint Strike Fighter program has an ongoing effort to support accreditation of the suite of models and simulations used in the requirements definition process. This is a multiphased effort that will culminate in an accreditation statement to accompany the Joint Operational Requirements Document that covers both code and input data for all of the M&S in the core suite. While the emphasis to date has been on the M&S code, there have been three ongoing efforts which are directly related to establishing the credibility and suitability of input data used in the M&S suite. The first effort is related to engagement level modeling of AAA systems. At the request of the JSF Director of Requirements, the model manager for the Radar Directed Gun System Simulation (RADGUNS) has prepared data sheets for each of the threats modeled which trace the data internal to the code to its original source. The effort made a substantial contribution to the body of V&V data on this simulation. These data sheets are available to the RADGUNS user community. The second area of effort is related to input files for mission level model. JSF has put substantial effort into developing extensive input files for the Simulated Warfare Environment Generator (SWEG) which describe the Generic Composite Scenario. Because JSF is both the producer and the user of these files, creation and maintenance of a gamebook and a pedigree document are an integral part of the long-term development effort. The gamebook describes the scenario and pedigree document, and traces the sources of data and the transformations that have been used to make the raw data appropriate to the scenario and the

model. The third area of effort has been at the campaign level. JSF has used input files for THUNDER which were developed by the Aeronautical Systems Command (ASC) at Wright Patterson Air Force Base. Although the files have been tailored somewhat for JSF, the baseline version of the files is described in extensive pedigree documents developed at ASC. ASC's pedigree process is described in Nancy Clements and Larry Beasley's paper "Pedigree Database Process Road to VV&C" referenced in the bibliography section of this Appendix. The VV&A Master Plan for JSF is currently being revised to reflect the data specific V&V efforts which will be conducted in FY99. The revision will incorporate lessons learned from the VV&C Tiger Team and will thus not be completed until the Tiger Team has concluded its efforts.

Appendix D

Data Quality Metadata Template

Scope

For this discussion of M&S data quality and M&S verification and validation (V&V) and accreditation, the following paradigm is defined:

Data quality (DQ) is established at the data producer level. That is: data producers generate data to a specification that has some basis in representing an intended ‘real world’, and their job is to produce their data to meet that objective. They conduct data V&V in support of their data quality efforts.

Whereas,

Model and simulation users put that data quality information to use in conducting their M&S V&V and Accreditation. That is: model and simulation users include data as an integral part of their model or simulation during the assessment of V&V and Accreditation. These V&V and Accreditation activities are accomplished to ensure that the ‘best’ data available are used with their algorithms so that model or simulation results are credible. In application, the user cannot separate data from the algorithm. It is the combination of both that produces a result, and therefore data should be validated as part of model accreditation.

Users rely on producer statements about data quality as a basis for their V&V and Accreditation efforts.

Data Quality

Data quality can be defined in many ways, but intuitively the quality of data is a measure of how well the data serve the purpose for which they were produced. All data are produced for a purpose, and the quality of that produced data is directly tied to whether it meets the requirements of that purpose.

Among other things, data quality should include some notion of the appropriateness of data for a specified use. However, there is no reason the data cannot be put to a different use as long as the user understands the requirements that the original data met and has some confidence that the data can meet the new use requirements. On the other hand, even when data are consistent and accurate, they may not be suitable for use in a specific model or appropriate for a specific application. They may be incompatible with the requirements of the model or may be based on assumptions that are inconsistent with the model’s intended use. Therefore it is up to the user to determine the appropriateness of the data for use in the model or simulation. The credibility of the model or simulation depends on the credibility of the data no less than the credibility of the model or simulation itself.

DQ is a data producer function. That is, data quality processes, including producer V&V, are conducted against the producer's specification. The results are then provided to the users who determines the appropriateness of the data for their specific application.

The assessment of data quality is inherently complex and cannot be represented by a simple numeric value. Rather, it is indicated by the sum of a myriad of bits of information about the data that are captured during the data production process and made available to the user. Thus an extensive amount of metadata is needed to totally describe the quality of data. This metadata can be organized into a template to provide a comprehensive and understandable listing.

Data quality management is an approach to improving both the overall quality of the data and the understanding and confidence in that quality. The template presents a comprehensive list of metadata fields, which when filled out by the producer, should improve the understanding of the quality of data specifically used in M&S. It will also provide significant information that can be used in completing the model or simulation V&V and Accreditation process. This template should help temper the concept that data quality is in the "eye of the beholder," whether that is the eye of the producer or user. However, only the user of the data can explicitly state whether the data are of high enough quality for the intended purpose.

How The User Can Put The Template To Use

The DQ Metadata Template is designed to guide users in identifying the type of producer-generated DQ information they should be looking for to support their V&V and Accreditation activities. The more metadata available, the easier and more comprehensive the user's V&V and Accreditation efforts will be.

The model or simulation user would conduct a review of the DQ metadata to determine if the data could fill the data needs of the model or simulation. Before obtaining the data, the model or simulation user could peruse the general metadata entries identified on the template to determine if the data appeared appropriate for the intended use. If the 'first glance' appeared favorable, the model or simulation user could then conduct a further assessment based on the multiple detailed metadata fields. After the data were obtained from the producer, the model or simulation user could use the V&V history, source credibility, data quality, etc., metadata fields to support the planned V&V and Accreditation activities.

The model or simulation user might study the metadata using the following sequence:

1. Description (including resolution, meaning, intended uses, etc.),
2. Sources and credibility of the sources,
3. Quality information – completeness, accuracy, validity, currency, etc,
4. Quality checks and V&V activities conducted by the producer, etc.,

5. Compliance with standards.
6. Other metadata that help identify if the data are appropriate for the intended use.

Data Quality Metadata Template

Quality metadata are described for three levels: the Database (DB) level, the Data Element (DE) level, and the Data Value (DV) level. Each of these quality metadata levels has three components: descriptive information, specification information, and quality information. The template of suggested quality metadata is shown in Tables 1-1 to 3-3.

A top down approach should be taken to capture DQ metadata. Metadata should be filled out at the DB level first, followed by the DE level, and finally the DV level. DE level metadata would only be needed if they are different from the DB level metadata, and DV metadata would only be needed if they are different from DE level metadata. The next higher level of metadata is usually a more general statement of the specific metadata at the lower levels.

Quality metadata should be included with the data in a way that makes capturing and subsequent access to the information most efficient. This conforms to the usual system information approach where there is a database of instance values (exact values in a specific field within the data set) and an associated Data Element Dictionary (DED) containing metadata. The method of incorporating quality metadata into the overall DB design is unique to the process owner.

The metadata associated with data system quality is usually textual in format. It should provide a characterization of the data, the organization providing the data, and the activities that resulted in creation of the data. The metadata design should be sufficient to describe data inputs, internal data processes, transformations, and outputs to the User.

Metadata Prioritization

The list of metadata needed to support User V&V and Accreditation is extensive. If every metadata field were required, it would overwhelm the data producer and dilute the effort to provide a core set of metadata in support of user V&V and Accreditation. To set a reasonable scope for producer DQ efforts, each item was ranked in importance to the model or simulation user. Rankings are:

- 1 Essential,
- 2 Recommended,
- 3 “Nice to have.”

There are many items on the list that are not self-explanatory. Users from different segments of the M&S community have different ideas of what a particular metadata field describes, and therefore have different opinions about how necessary that particular metadata field is to support

user V&V and Accreditation. A data dictionary was added to the template to define each metadata item.

Table 1-1. DQ Metadata at the Database Level – Descriptive Information

Priority	Metadata	Definition
1	Description including meaning of exceptions, nulls, uncertainties	An overall textual characterization of the DB, including a discussion of its intended range of appropriate uses and any constraints on its intended use. Includes a discussion of the meaning of exceptions, nulls, and uncertainties within the DB.
1	Access requirements	Information about the requirements for gaining access to the DB, including owning agency, point of contact (phone and FAX numbers, e-mail, and postal addresses, etc.), what restrictions apply to its access and use, and any copyright or foreign distribution requirements or constraints that apply to it. Also includes any user requirements, such as special S/W or H/W, special pre- or post-processing, etc.
1	Resolution and rationale	A description of the overall level of resolution of the data in the DB, including the reasons for choosing this level, in terms of the stated purpose of the DB and its design, source, and relationship to other DBs. If the DB cannot be characterized as having a single, uniform level of resolution, the lack of consistency must be explicitly stated and justified in terms of the intended use of the database.
1	Usage (who, when, for what, with what model)	The history of the DB, including a POC for each instance of use and a description of what the DB was used for.* (Linked to V&V audit trail)
1	V&V audit trail	A history of quality assessment efforts applied to the DB, including records of V&V results. This should be linked to the usage history metadata above and to the metadata for the V&V audit trail at the data element and data value
1	Classification	Simple statement about the security level of the database.
1	Release authority	Organization/Agency and/or POC authorized to release all or part of the DB for use.
2	Data Sources	Discussion of where the source information contained within the DB came from (immediate source and original source) including agency/organization, POC, etc.
2	Source credibility	Discussion of the credibility of the agency/organization/POC providing the data in the database. Identify who has certified the immediate and original data sources as credible.
2	Descriptions of processes used	A discussion of the processes that are used to derive, generate, collect, and transform the data (and metadata) in the DB.
2	Version history	Explicit version documentation showing which agents revised the DB at which times and what kinds of changes they made, including descriptions of changes to structure, content, or meaning of both data and metadata at the conceptual level. An official record of changes to a DB by the agency or organization that owns and has responsibility for maintaining it.
3	Overall database status	Concise statement of the condition of the DB, indicating whether it is in transition, how stable it is, and what expected future changes will affect it. This includes 'configuration management' information that explains how versions are maintained and by whom, and references to descriptions of any standard methodology of software used for version control.
3	Description /rationale for structure and design	A textual characterization of the DB design and structure and a discussion of their rationale, relating them to the intended purpose and use of the DB. It should include such overall aspects as the language and format of the DB. The rationale serves as consistency check against the discussion of intended use.
3	Global relationships to other databases	An explicit description of the overall relationship of this DB to any others. It should explain any semantic and/or historical relationships between this DB and any others, making clear whether the relationship is expected (or required) to continue to hold true.
3	Reproducibility	The ability of the producer to provide exact replications of a previously supplied DB (new database instance). **
3	Cross DE distribution measurement info	A description of statistical checks to be applied to distributions of values across different data elements in the DB. (Metadata for such checks applied to distributions of values of single data elements should be specified at the data element level.)
3	Rationales for using the processes	Discussion of the reasons for choosing each process used for the derivation, generation, collection, and transformation of data (and metadata) within the DB.
3	Owners of the processes (development, maintenance, execution)	Agents responsible for choosing and developing the processes used for the derivation, generation, collection, and transformation of data (and metadata) within the DB, including agency/organization, POC, etc.
3	Update cycle information	A statement of how often, how regularly, and how extensively the DB is expected to be updated. Overlaps with 'currency' metadata, but the emphasis here is on giving an overview of when, how, and by whom the DB is revised or reissued, rather than on how current the information within it may be at any given time.

* Note: Instance Data is defined as exact values in a specific field within the data set.

** Note: Instance/Session of a DB is defined as an individual, populated data set.

Table 1-2. DQ Metadata at the Database Level – Specification Information

Priority	Metadata	Definition
2	System specification and design document	Formal description of the database structure and content.
2	Standards	Compliance with International, National, DoD, or M&S Community data standards, e.g., DDDS.
2	Specific Data Sets	Instances/sessions of the DB**. A discussion of each data set for which the given DB design is used. Each instance of a DB may be static or dynamic, and this aspect should be documented as part of its description.
3	DBMS information including version and CM	Description of database management system current version, version history.
3	Logical Data Models	Discussion/depiction of the data that must be stored in order to satisfy user needs, and its interrelationships.
3	Physical Data Models	Discussion/depiction of how data elements are implemented and stored in the DB.
3	Process Flow Models	Discussion/depiction of process streams and associated data elements.
3	Data Flow Models	Discussion/depiction of how data flows and is processed within the DB.

**Note: Instance/Session of a DB is defined as an individual, populated data set.

Table 1-3. DQ Metadata at the Database Level – Quality Information

Priority	Metadata	Definition
1	Accuracy according to positional and attribute specs	A discussion of the degree of agreement between a datum and source assumed to be correct (real world).
1	Completeness in features and attributes	A discussion of how the DB satisfies all data content demands or requirements.
1	Currency	A discussion of how up-to-date the DB is.
2	Logical consistency	A discussion of how the DB is maintained so it is free from excessive variation or from contradiction of expected/standard ranges.
2	Flexibility of design	A discussion of the potential ability of the DB design to support 'non-traditional' uses.
3	Clarity of design	A discussion of how the DB is designed to allow ease of understanding of the underlying structure and content.
3	Timeliness	A condition that requires that a DB be provided at the time required or specified. A discussion of how quickly the DB can be generated from the time of request.

Table 2-1. DQ Metadata at the Data Element Level – Descriptive Information

Priority	Metadata	Definition
1	Description including meaning of exceptions, nulls, uncertainties	An overall textual characterization of the semantics of the DE, including a discussion of what it is intended to represent and what it is not. Includes a textual characterization of the meaning of nulls or any exceptional, special, or unknown values of this DE.
1	Degradation information	The 'mode' in which values of a DE are expected to degrade over time: some values become continuously less accurate or less meaningful as they age, whereas others remain entirely valid until they 'expire', i.e, when some event changes the reality which they represent.
1	Aggregation, derivation, or transformation information	Whether and how values for this DE are derived from other data, including a discussion of any grouping or other derivation method used to generate this DE, and any other data values used in this derivation, or any transformations that are applied in generating this DE
1	Resolution and precision	The level of detail and number of significant digits in numerical values of this DE, including any representation issues (such as precision limits imposed by field-length or encoding).
1	V&V audit trail	A high-level history of quality assessment efforts applied to the DE, allowing certification results to be recorded. This should be linked to the usage history metadata above and to the metadata for the V&V audit trail at the database and data value
2	Source or sources and de-conflicting processes and rationales	Where the source information contained within the DE came from (immediate source versus original source) including agency/organization, POC, etc. Includes a qualitative, textual discussion of the 'goodness' of the DB including information about the agency/organization, POC, etc making the credibility assessment. It should include a discussion of who has certified the certification official as credible.
2	Changes or modifications of source element and effect on this DE	The update-cycle metadata for the DB as a whole, focusing on the revision of a particular DE, which may be different for different DEs within the DB. Different levels of revision may occur, corresponding to more or less complete revisions by more or less authoritative sources or agents.
2	Accessibility	The state of maintaining a DE in a condition that provides the ability to retrieve the specific information needed by the user.
2	Release authority	Organization/Agency and/or POC authorized to release the DE.
2	Process control data	A historical record of how the generation of the DE was controlled, including descriptions of process modeling methodology, or external descriptions of the process in some appropriate form or publication.
2	Audit trail of changes to element	A history of any changes to the definition of this DE, i.e., its type, domain, units, or meaning., including times and sources of any such modifications and the changes themselves.
2	History of changes or modifications	Explicit version documentation showing which agents revised the DE at which times and what kinds of changes they made, including descriptions of changes to structure, content, or meaning of both data and metadata at the conceptual level. An official record of changes to a DE by the agency or organization that owns and has responsibility for maintaining it.
3	Update cycles	How often, how regularly, and how extensively the DE is expected to be updated. Overlaps with 'currency' metadata, but the emphasis here is on giving an overview of when, how, and by whom the DE is revised or reissued, rather than on how current the information within it may be at any given time.
3	Reproducibility	The ability for the users to reuse the data elements retrieved.
3	Classification	Simple statement about the security level of the data element.
3	Constraints	A description of any limitations or restrictions that apply to this DE, beyond those implied by its domain and data type, including desirable constraints such as DB 'business rules'.
3	Relationships to other data/DB Description	How this DE relates to other DEs in this DB or other DBs, including descriptions of consistency or statistical checks to be applied to distributions of values of single DE.

Table 2-2. DQ Metadata at the Data Element Level – Specification Information

Priority	Metadata	Definition
	ENTITY METADATA	
1	Entity Name	The label of an entity; must be a noun or noun phrase with the entire phrase connected by hyphens; must accurately reflect its characteristics (attributes), especially its domain.
1	Definition Text	The narrative description of what an entity is.
3	Comment Text	Additional narrative description of an entity.
3	Version Identifier	Used for configuration management of the object; based on modifications of approved standards; system-generated based on actions taken by the appropriate data administrators.
3	Counter Identifier	The “record number” within the DDDS *** (system generated); unique to the category of data standard.
3	Entity Status	The stage within the approval cycle; DDDS generated based on actions taken by the appropriate data administrators.
3	Functional Area Identifier	An indicator of the functional area of responsibility within the DoD to which an entity or DE belongs. Can be selected from a list in the DDDS. Areas may be added/modified based on customer request supporting changes to missions of the Department.
3	Entity Steward Name	Dependent on functional area; a steward is responsible for certain functional areas and the validity of data contained in standard DEs within the functional area. This is DDDS generated based on the functional area identifier.
2	Entity Using Model Name	The association of an entity with a logical data model.
	DE METADATA	
1	Standard DE Name	The label of an attribute, comprised of a minimum of an entity and generic element; may contain property modifier(s) providing additional descriptions; may utilize generic data; must be a noun or noun phrase and accurately reflect the characteristics (metadata) of the attribute, especially domains.
3	Counter Identifier	The “record number” within the DDDS (system generated); unique within a category of data standard.
3	Status Code	The stage within the approval cycle; DDDS generated based on actions taken by the appropriate data administrators.
3	Component Code	The organization to which the creator is assigned.
3	Access Name	An abbreviated name representing a specific DE. An access name is used to reference a DE in a DB and must conform to the syntactical requirements of the database management system (DBMS) or programming language of the application in which a DE is used. The maximum length for an access name is 18 characters. The DDDS will generate an access name if one is not provided.
2	Data Type Name	The naming convention for how domain values are stored in a DB. The generic DEs with class words having a data type of “integer” will be modified with a comment (comment text field) as follows: DEs using the data type “integer” should fit into a 32 bit representation. The high range value of a signed integer is limited to “2.1 billion” (in the range -2^{31} to $2^{31}-1$); data requirements of greater values should use the data types “floating point” or “fixed point”.
3	Functional Area Identifier	An indicator of the functional area of responsibility within the DoD to which an entity or DE belongs. Can be selected from a list in the DDDS. Areas may be added/modified based on customer request supporting changes to missions of the Department.
3	Security Category	A classification assigned to the data element domain value identifiers stored in some physical media to show the level of protection required to prevent their disclosure.
3	Max Char Count	The field length of the data; it should be large enough to accommodate all requirements, yet precise enough to allow for accuracy.
3	Timeliness Identifier	A description of the frequency of updates to the domain; this information will inform implementors/database administrators when to refresh their tables.
3	Standard Authority ID	The identifier of the DoD component, government department, and national or international organization that approved the DE domain value identifiers for a standard DE.
3	Justification Category	The classification of the positional alignment of domain values in a storage field.
3	Steward Name	Dependent on functional area (DDDS generated based on the functional area identifier); a steward is responsible for certain functional areas and the validity of data contained in standard DEs within the functional area.

Table 2-2. DQ Metadata at the Data Element Level – Specification Information (Cont.)

3	Derivation Code	Describes if the attribute/data element is atomic or the category of derivation. The two categories of derivation are derived and composite. a. Composite DE: Composite DEs describe multiple concepts. When a DE is formulated to describe multiple concepts, its definition and meaning can easily partially overlap with the definition of another DE. This redundancy sets the stage for data inconsistencies, increases system maintenance costs, and restricts the use of a DE to a narrow range of applications. When identifying a composite DE that is required to be used within a system, all pieces of data which make up this composite DE must be approved DEs within the DDDS. The names of the approved DEs that make up the composite should be recorded in the “comment text” field of the DDDS. b. Derived DE: Derived DEs represent the results of computational operations performed on other DEs. The computations may involve algorithms supported by two or more DEs within a single entity instance, or algorithms summarizing DE values across multiple entity instances within a single entity or across multiple entities. The algorithm is recorded in the “formula definition text” field of the DDDS.
3	Domain Value Type ID	Distinguishes the kinds of domain value identifiers in a DE (qualitative or quantitative).
3	Functional Abbreviation Access Name	An abbreviated name representing a specific DE. A functional abbreviation access name is used to reference a DE in a DB and must conform to the syntactical requirements of the DBMS or programming language of the application in which a DE is used. The maximum length for a functional abbreviation access name is 30 characters.
3	Authority Reference Text	The official regulation, policy, guidance, etc. that specifically requires the DoD to capture, maintain, exchange this data; the text must directly reference the data.
2	Source List Text	The authoritative reference containing the official list of domain values.
2	Domain Definition Text	A narrative expressing the way the allowable domain value identifiers will be represented.
2	Domain Value Identifier	The actual codes that provide access to lists of categories of objects. A complete list of domain values is required for data elements having a specific domain.
2	Domain Value Definition Text	The narrative description and explanation of the codes. Required if there are domain values.
2	DE Using Model	The association of a DE with a logical data model.
1	External DE Relationships	Provides a mapping to external data standards.
	Quantitative Attributes	
1	Formula Definition Text	A narrative expressing the algorithm which calculates the value of a derived data element.
1	Unit Measure Name	The word/words that express the terms in which the dimension, quantity, or capacity of an object can be stated. a. “When Unit of Measure name is applicable and more than one possible unit of measure exists, two documentation options are available. If unit of measure is convertible to other units of measure through standard algorithms (i.e., Distance: feet converted to meters and vice versa), then the single most commonly used unit of measure should be entered. If multiple possible units of measure exist that cannot be converted using standard algorithms (i.e., Cable Quantity: cable by weight or cable by length), then a separate attribute (DE) should be added for managing/tracking the appropriate unit of measure for each instance of the entity.” b. “N/A” is an acceptable entry for DEs classified as Date or Time.
1	Quantitative Accuracy ID	An indication of how accurate a DV must be.
1	Low Range	A string of up to 20 integers which indicates the smallest allowed domain value when a DE’s domain is expressed as a range of acceptable values.
1	High Range	A string of up to 20 integers which indicates the largest allowed domain value when a DE’s domain is expressed as a range of acceptable values.
1	Decimal Place Count Quantity	The integers that indicate the quantity of numeric digits allowed to the right of the decimal point in a quantitative fixed-point domain value.
	Qualitative Attributes	
2	Accuracy Number %	An indication of how accurate a qualitative domain value must be. 1-100 percent.

*** Note: The Defense Data Dictionary System (DDDS) is the DoD repository of standard data containing standardized data entities, attributes, and relationships contained in a data dictionary and supporting data models. It is intended for use across the DoD enterprise to support data interoperability and reuse.

Table 2-3. DQ Metadata at the Data Element Level – Quality Information

Priority	Metadata	Definition
1	Business rules for data element and cross data element dependency	Atomic-level statements that define or constrain what does/does not define a DE, what changes or manipulations may be made to the composition of a DE, and what second and (as applicable) third order effects may occur as a result of such changes/manipulations..
1	Metrics applied along with descriptions, business rules, and rationale	Verification/validation/certification (as applicable) objective techniques (case-based reasoning, statistical reasoning), rules followed for application of the techniques used, and supporting logic for their use.
1	Results of metrics applied along with addressing the metadata attribute specifications	Outcomes of metrics and their relationship to established DE composition characteristics, constraints; pass/fail status, in terms of compliance with business rules parameters.
1	Appropriateness for Intended Use	An evaluation (as a result of user V&V) of how suitable this DE definition is for a specific intended use.
2	Description/explanation of results of metrics applied and metrics not applied for this use or period of use	Analysis of the measurement results; 'quality' of pass/fail, deviation of measurements realized, reasons for deviations (if identified), predictability that future DV instances will be within acceptable ranges. Include identification of any standard measurements not used, and why.
3	Examiner information	Information identifying the organization/individual determining metrics, sufficient for follow-up contact.
3	Data/time information of examination	Date/time 'stamp' of the measurement activities.

Table 3-1. DQ Metadata at the Data Value Level – Descriptive Information

	Metadata	Definition
1	Definition (if more specific than at DE or if applied to data value groupings)	An overall textual characterization of the actual instance values of data.
1	Aggregation, derivation, or transformation information	Whether and how this DV was derived from other data, including a discussion of any grouping or other derivation method used, and any other data values used in this derivation, or any transformations that are applied in generating this DV.
1	V&V audit trail	All evaluations that have been performed on the data value, linked to usage history and the V&V Audit Trail information at the database and DE levels.
2	Source	Discussion of where the DVs came from, including agency/organization, POC, etc.
2	Caveats or exceptions (for DV acceptance if not within accepted values)	Textual annotations to explain DB instance-specific data values, including any annotations or comments about exceptional values or missing data.
2	Process control data	A discussion/depiction of how the generation of the DV was controlled, including descriptions of process modeling methodology, or external descriptions of the process in some form or publication.
3	Time of generation	Date/time 'stamp' of the DV generation.
3	Cross data value, associative data value, or data value grouping information	A description of consistency restrictions or limitations across different DVs.
3	Update cycle or next expected update	A statement of how often, how regularly, and how extensively the DV is expected to be updated emphasizing an overview of when, how, and by whom the DV is revised or reissued, rather than on how current the information within it may be at any given time.

Table 3-2. DQ Metadata at the Data Value Level – Specification Information

Priority	Metadata	Definition
2	Specifications in terms of processes or algorithms with which the DV or DV groupings must comply	A discussion of the business rules specifying the algorithms or transformation processes applicable to generation of the DV or to the appropriate groupings of DVs.
3	Specifications applied to the DV because of cross DV dependencies	A discussion of the business rules specifying cross DV dependencies.
3	Specifications applied to DV groupings	A discussion of the business rules specifying appropriate groupings of DVs.

Table 3-3. DQ Metadata at the Data Value Level – Quality Information

Priority	Metadata	Definition
1	Business rules for DE and cross DE dependency	Atomic-level statements that define or constrain what is/is not recorded as data, what changes and/or manipulations may be made to the data, and what second and (as applicable) third order effects may occur as a result of such changes/manipulations.
1	Metrics applied with descriptions, business rules, and rationale	Verification/validation/certification (as applicable) objective techniques (case-based reasoning, statistical reasoning), rules followed for application of the techniques used, and supporting logic for their use.
1	Results of metrics applied, addressing metadata attribute specifications for data value or data value groupings	Outcomes of metrics and their relationship to established data value characteristics, constraints; pass/fail status, in terms of compliance with business rules parameters. Includes a qualitative assessment of accuracy.
1	Qualitative Measure of Accuracy	A discussion of the overall state of the accuracy of the DV based on producer's view of how well the specification was met.
2	Description/explanation of results of metrics applied/not applied for this use or period of use	Analysis of the measurement results; 'quality' of pass/fail, deviation of measurements realized, reasons for deviations (if identified), predictability that future data value instances will be within acceptable ranges. Include identification of any standard measurements not used, and why.
3	Examiner information	Name, organization, title, phone number, fax number, email for person conducting the measurement of DV quality.
3	Date/time information of examination	Date/time 'stamp' of the measurement activities.

Appendix E

Revised M&S Life Cycle Process Model

Purpose

The M&S Life Cycle Process model was revised to provide insight into elements of the data verification and validation problem that may still remain to be addressed because of insufficient understanding or experience, to identify areas requiring more guidance, and to generate additional information from which conclusions and recommendations could be drawn. DoD Components and other organizations may wish to use the model to assist in drafting guidance, creating necessary training, or support other related efforts.

Approach

The basis of the revised M&S Life Cycle Process model is the M&S Life Cycle Process model created to support creation of Defense Modeling and Simulation Office (DMSO) *Verification, Validation, and Accreditation (VV&A) Recommended Practices Guide* and the generic user data VV&C process model resulting from the 1995 DMSO sponsored VV&C project. The original M&S Life Cycle Process model was augmented with data verification and validation activities in ways reflecting the most sensible process based upon the experience of the participants. Activities identified in the generic user VV&C process model were inserted into the M&S Life Cycle Process model and appropriate relationships and interactions were defined. Additional activities were appended where needed.

Results

The resulting model is a technical document depicting the integration of data verification and validation activities into the M&S verification, validation and accreditation process and describing how an entire M&S life cycle process could be executed. Key findings observed during the creation of this model include:

1. Data certification should not be a mandatory part of the V&V process. Data certification corresponds to data acceptance, and is frequently implicit.
2. Data V&V and M&S V&V activities are distinct yet complementary and interdependent. In particular, data validation and M&S validation at the application level are inextricably intertwined.
3. Data V&V and M&S V&V activities take place both during model development and during application preparation. The activities differ for each phase.

Model

The M&S Life Cycle model is presented as a set of IDEF0 diagrams. The diagrams are supplemented with three reports: the first presenting the definitions of the activities making up the model; the second presenting definitions for all arrows; and the third associating each activity with the ICOMs for which the activity is either a source or a destination. The model is available as a complete file as developed using the program, BPWin, Version 2. The diagrams are also available as a Power Point file. Please contact the DMSO for information on obtaining them.

IDEF0 Modeling Conventions

IDEF0 is a standard means of modeling (describing) processes. In the present case, the process being modeled is the modeling and simulation life cycle. IDEF0 prescribes a set of hierarchical diagrams, each one composed of activity boxes, that are interconnected by arrows depicting the relationship (e.g., passage of information) between the activities. Both activity boxes and arrows are named – activity boxes with a verb phrase describing the action that takes place within the activity, and arrows with noun phrases describing things relevant to the activity to which they are attached. Arrows may also connect one of the four edges of the diagram with an activity box.

By convention, each diagram (save the context diagram at the top of the hierarchy) contains between two and six activity boxes. The set of activities appearing in a single diagram completely (although perhaps not comprehensively) describe the process that is the title of the diagram. THERE ARE NO CONTINUATION PAGES, OR OFF-PAGE CONNECTORS IN AN IDEF0 MODEL.

IDEF0 activities and arrows provide typical input-process-output (IPO) information and more. Each input and output is represented by a labeled arrow. By convention, all inputs to an activity box enter at the left side of the box and all outputs originate from the right side of the box and lead to the activity(s) in which the information depicted by the arrow is used. If the information comes from or goes to an activity on a different diagram, the arrow begins or ends at the border of the diagram.

In addition, IDEF0 models use arrows to depict “constraints” and “mechanisms.”

- Constraints are factors that influence the freedom of an activity to be performed in an arbitrary way (e.g., a standard dictating certain aspects of how the activity must be carried out, required formats for the outputs, available resources). Constraints differ from inputs in that they are not changed by the activity, nor are they transformed into outputs by the activity. Constraints are frequently imposed by factors or organizations outside the ones charged with implementing the process.
- “Mechanisms” document the means (e.g., tools, machines, people) by which the activity will be completed. Although mechanisms frequently identify resources required to

accomplish a task, it does not document the consumption of resources necessary to complete the activity. For instance, the “Accreditation Authority” (presumably a person with a staff) is a mechanism required to accredit a model or simulation and is so indicated in the M&S Life Cycle Process model. However, the IDEF0 model does not, and is not intended to, address the number of staff hours of the accrediting authority’s effort is required to achieve accreditation.

By convention, constraints enter an IDEF0 activity box at the top edge, and mechanisms enter at the bottom edge. All arrows, then, are either Inputs, Constraints, Outputs or Mechanisms (ICOMs).

Activity boxes are labeled with the name of the activity in the center and the activity number (e.g., A-0) in the lower right corner. The activity number denotes its relationship to the remaining activities in the hierarchy. They provide a roadmap for where one is in the model, and where one wants to go. However, this relationship is based on information flow and is not temporal in nature. The short diagonal slash in the upper left corner of an activity box signifies that no further decomposition of the activity in this model. It does not imply that no further decomposition is possible, just that none has been provided.

Model Notes

1. The M&S Life Cycle Process model has been modified to accommodate processes and activities directly related to the verification and validation (and certification) of data for use in models and simulations. For that reason, only those changes to the non-data activities and ICOMs necessary to support the introduction of specific data activities were introduced. Exceptions to this are the introduction of decision logic in the **Initiate Application** activity supporting a “make or buy” decision and the addition of “Modify” to many of the “Develop M&S” activities. If the decision is “buy” then many M&S development activities are bypassed or changed. These changes explicitly acknowledge the increasing role of legacy M&S in the scheme of things. They also acknowledge the associated need to use new or modified sets of instance data to make the M&S reusable.
2. IDEF0 modeling and model diagrams do not imply any sequence between or among activities on the same sheet. The left to right (and top to bottom) arrangement are merely a presentation convenience, done more for graphical considerations than anything else. It is therefore important to recognize that any activities on a single page can start, continue, and complete in an arbitrary sequence, and especially may continue concurrently.
3. A sequence for completion of an activity can often be inferred by the Inputs and Constraints associated with the activity. Some activities have an Input that can be inferred to be a trigger that starts the activity – something like “Run Request” that initiates the “Apply M&S” activity.
4. At least for this IDEF0 model, all ICOMs should be individually considered as optional – that is, the appearance of (say) “V&V Report” as an output from an activity should be

interpreted as meaning, “if a V&V Report is called for, the activity for which it is shown as an output is the one that will produce it; or, “Data Certification Official” is shown as a mechanism for activities in which the official would participate, *if the data certification official were a participant at all.*

5. Based on the above comments, it should be evident that the IDEF0 model is primarily a technical document describing how a M&S Life Cycle Process could be executed. It is in no sense directive, although appropriate officials could use it, or parts of it to develop a specific process for a designated purpose. As a consequence, the definitions of activities and ICOM arrows are intended as exposition, not as official definitions. Although the Model Sub-group intended the definitions to be compatible with the various approved definitions related to M&S and VV&A, the primary goal was to make them helpful in explaining the model.
6. In our full-blown M&S Life Cycle Model, we have informally used the following conventions:
 - dotted lines depict feedback loops between activities
 - green is used to depict data-related activities and arrows
 - red is used to depict verification, validation, and/or accreditation-related activities and arrows
 - blue is used to depict activities directly related to the application which the M&S supports.

Notwithstanding, we have, on occasion, changed the colors on arrows to ease the task of following individual arrows through the maze that appears in some of the diagrams. In other words, arrow colors may have been selected for readability regardless of the conventions described above.

USED AT:	AUTHOR: VVCTT	DATE: 6/11/98	WORKING	READER	DATE	CONTEXT: TOP A-0
	PROJECT: Recommended Model	REV: 5/29/98	DRAFT			
			RECOMMENDED			
			PUBLICATION			
NOTES: 1 2 3 4 5 6 7 8 9 10						

**EXECUTE
M&S
LIFE CYCLE
PROCESS**
A0

**Initiate
Application**
A1

**Develop/Modify
M&S**
A2

**Collect
Review &
Prepare
Instance Data**
A3

**Apply
M&S**
A4

- Identify M&S Rqmts
- Formulate Plans
- Establish M&S Environment

- Develop Conceptual Model
- Develop/Modify M&S Design
- Implement M&S Design
- Perform M&S Integration

- Collect Data & Metadata
- Review Data
- Conduct Transform Data
- Initialize Instance Data Set(s)

- Prepare M&S For Use
- Use M&S In Application
- Analyze & Interpret Results
- Present M&S Results

NODE: A0	TITLE: EXECUTE M&S LIFE CYCLE PROCESS	NUMBER:
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USED AT:	AUTHOR: VVCTT	DATE: 6/11/98	WORKING	READER	DATE	CONTEXT: TOP A0
	PROJECT: Recommended Model	REV: 6/11/98	DRAFT			
			RECOMMENDED			
			PUBLICATION			
NOTES: 1 2 3 4 5 6 7 8 9 10						


```

graph TD
    A1[Initiate Application A1] --> A1.1[Identify M&S Rqmts A1.1]
    A1 --> A1.2[Formulate Plans A1.2]
    A1 --> A1.3[Establish M&S Environment A1.3]
    A1.2 --> T1[Collect Planning Information]
    A1.2 --> T2[Develop M&S Plan]
    A1.2 --> T3[Develop VV&A Plans]
    A1.3 --> T4[Develop Rqmts Specifications]
    A1.3 --> T5[Identify Environmental Planning Issues]
    A1.3 --> T6[Identify Input Data Rqmts]

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NODE: A1	TITLE: Initiate Application	NUMBER: <div style="border: 1px solid black; height: 20px; width: 100%;"></div>
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	PROJECT: Recommended Model	REV: 6/11/98	DRAFT			
			RECOMMENDED			
			PUBLICATION			
NOTES: 1 2 3 4 5 6 7 8 9 10						

```

graph TD
    A1.2[Formulate Plans  
A1.2] --> A1.2.1[Collect Planning Information  
A1.2.1]
    A1.2 --> A1.2.2[Develop M&S Plan  
A1.2.2]
    A1.2 --> A1.2.3[Develop VV&A Plans  
A1.2.3]
    A1.2.3 --> I1[Identify VVA Rqmts]
    A1.2.3 --> I2[Select VVA Tools & Techniques]
    A1.2.3 --> I3[Develop Model/Data V&V Plans]
    A1.2.3 --> I4[Develop Accreditation Plan]

```

Formulate Plans
A1.2

Collect Planning Information
A1.2.1

Develop M&S Plan
A1.2.2

Develop VV&A Plans
A1.2.3

- Identify VVA Rqmts
- Select VVA Tools & Techniques
- Develop Model/Data V&V Plans
- Develop Accreditation Plan

NODE: A1.2	TITLE: Formulate Plans	NUMBER: <div style="border: 1px solid black; height: 20px; width: 100%;"></div>
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	PROJECT: Recommended Model	REV: 5/29/98	DRAFT			
			RECOMMENDED			
			PUBLICATION			
NOTES: 1 2 3 4 5 6 7 8 9 10		A1.2				

Develop VV&A Plans
A1.2.3

Identify VVA Rqmts
A1.2.3.1

Select VVA Tools & Techniques
A1.2.3.2

Develop Model/Data V&V Plans
A1.2.3.3

Develop Accreditation Plan
A1.2.3.4

- Review M&S Rqmts
- Determine Acceptability Criteria
- Determine Model V&V Rqmts
- Determine Data V&V Rqmts

- Determine Accreditation Assessment Approach
- Determine V&V Approach
- Select VVA Tools & Models

NODE: A1.2.3	TITLE: Develop VV&A Plans	NUMBER: <div style="border: 1px solid black; height: 20px; width: 100%;"></div>
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USED AT:	AUTHOR: VVCTT	DATE: 6/11/98	WORKING	READER	DATE	CONTEXT: TOP A0
	PROJECT: Recommended Model	REV: 5/29/98	DRAFT			
			RECOMMENDED			
			PUBLICATION			
	NOTES: 1 2 3 4 5 6 7 8 9 10					

Develop/Modify M&S
A2

Develop Conceptual Model
A2.1

- Construct Conceptual Model
- Verify Conceptual Model
- Validate Conceptual Model

Develop/Modify M&S Design
A2.2

- Develop/Modify Preliminary Design
- V&V Preliminary Design
- Develop/Modify Detailed Design
- V&V Detailed Design

Implement M&S Design
A2.3

- Build Model
- Verify Implementation
- Validate Implementation

Perform M&S Integration
A2.4

- Integrate Model(s)
- Verify Integration
- Validate Integration

NODE: A2	TITLE: Develop/Modify M&S	NUMBER: <div style="border: 1px solid black; height: 20px; width: 100%;"></div>
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USED AT:	AUTHOR: VVCTT	DATE: 6/11/98	WORKING	READER	DATE	CONTEXT: TOP A0
	PROJECT: Recommended Model	REV: 5/29/98	DRAFT			
			RECOMMENDED			
			PUBLICATION			
	NOTES: 1 2 3 4 5 6 7 8 9 10					

**Collect
Review &
Prepare
Instance Data**
A3

**Collect
Data &
Metadata**
A3.1

**Review
Data**
A3.2

- Select Data
- Verify Data Availability
- Verify Adequacy of Metadata
- Verify Instance Data

**Conduct
Transform
Data**
A3.3

- Evaluate Transformation Method(s)
- Transform Data
- Verify Transformed Instance Data

**Initialize
Instance
Data Set(s)**
A3.4

- Enter Data Into Data Sets
- Verify Entered Data

NODE: A3	TITLE: Collect Review & Prepare Instance Data	NUMBER:
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USED AT:	AUTHOR: VVCTT	DATE: 6/11/98	WORKING	READER	DATE	CONTEXT: TOP A0
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			PUBLICATION			
	NOTES: 1 2 3 4 5 6 7 8 9 10					

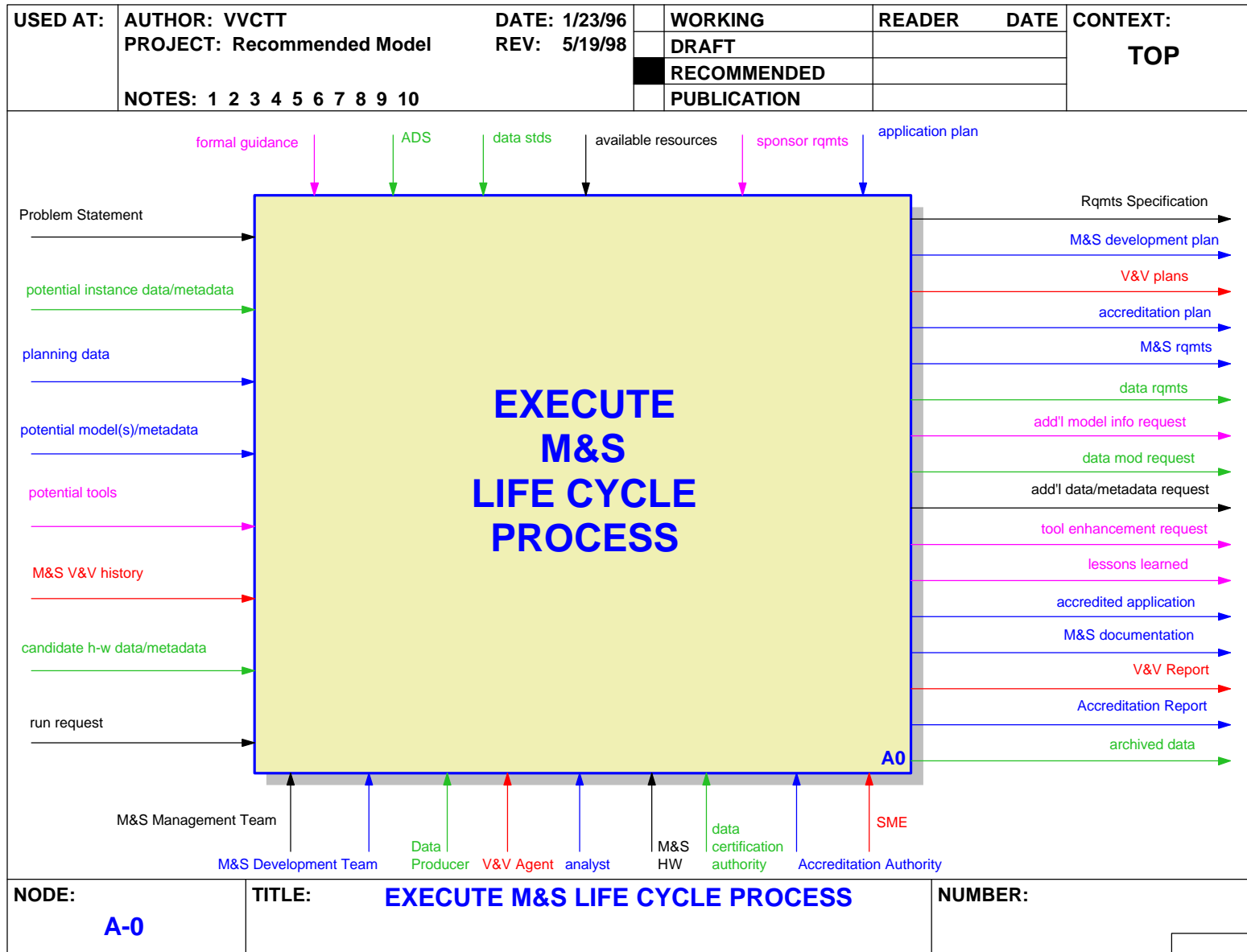
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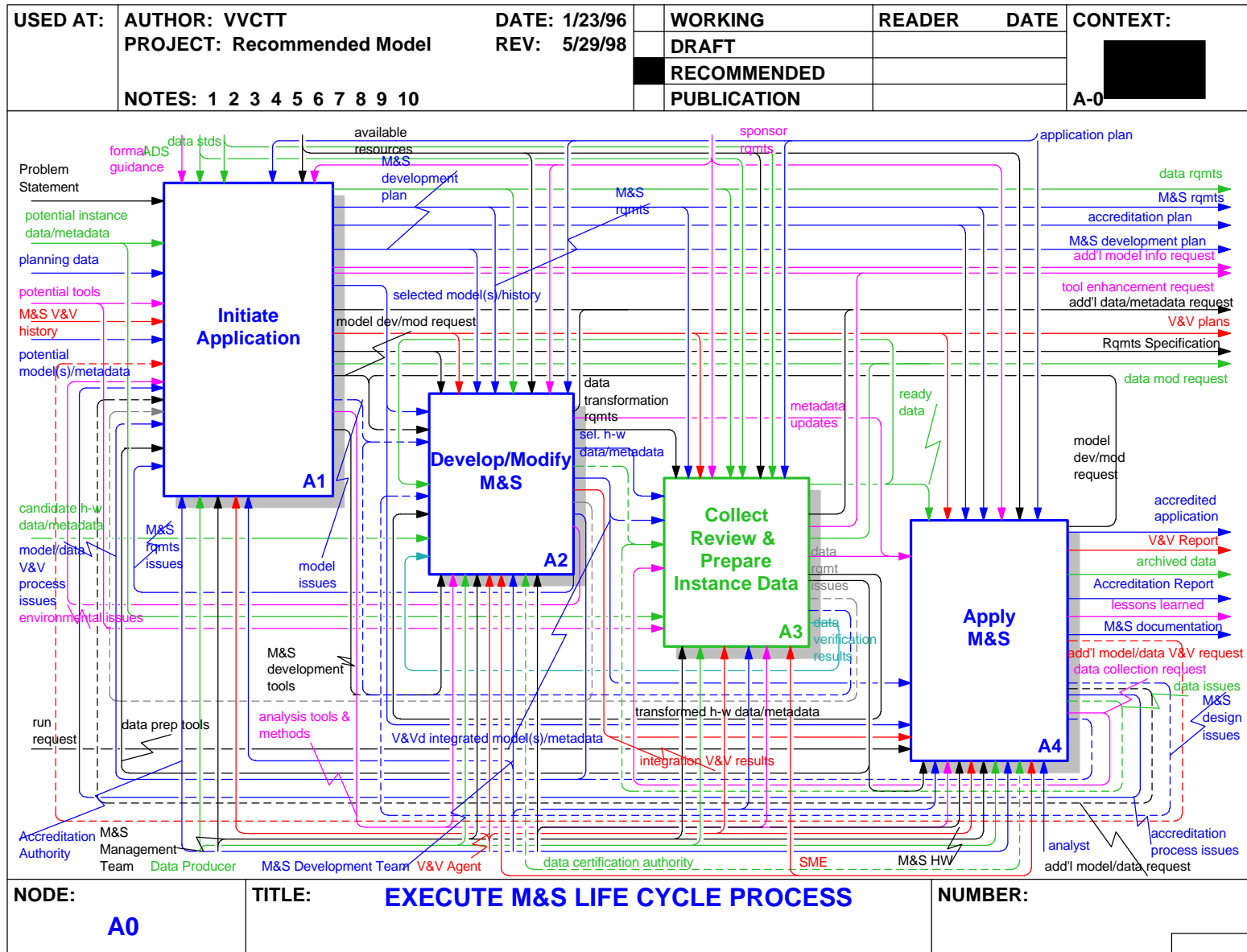
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A4] --> A4.1[Prepare M&S For Use  
A4.1]
    A4 --> A4.2[Use M&S In Application  
A4.2]
    A4 --> A4.3[Analyze & Interpret Results  
A4.3]
    A4 --> A4.4[Present M&S Results  
A4.4]

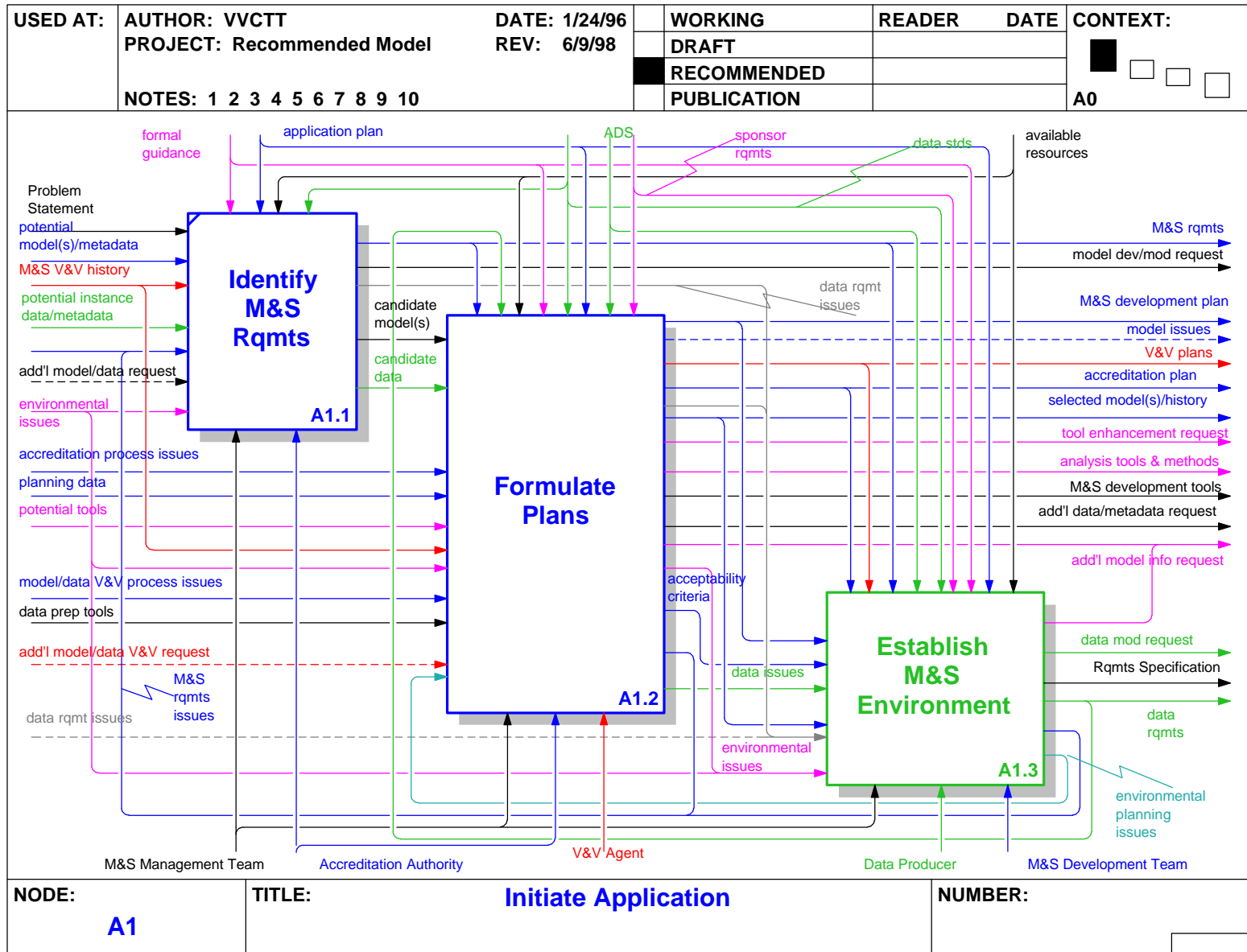
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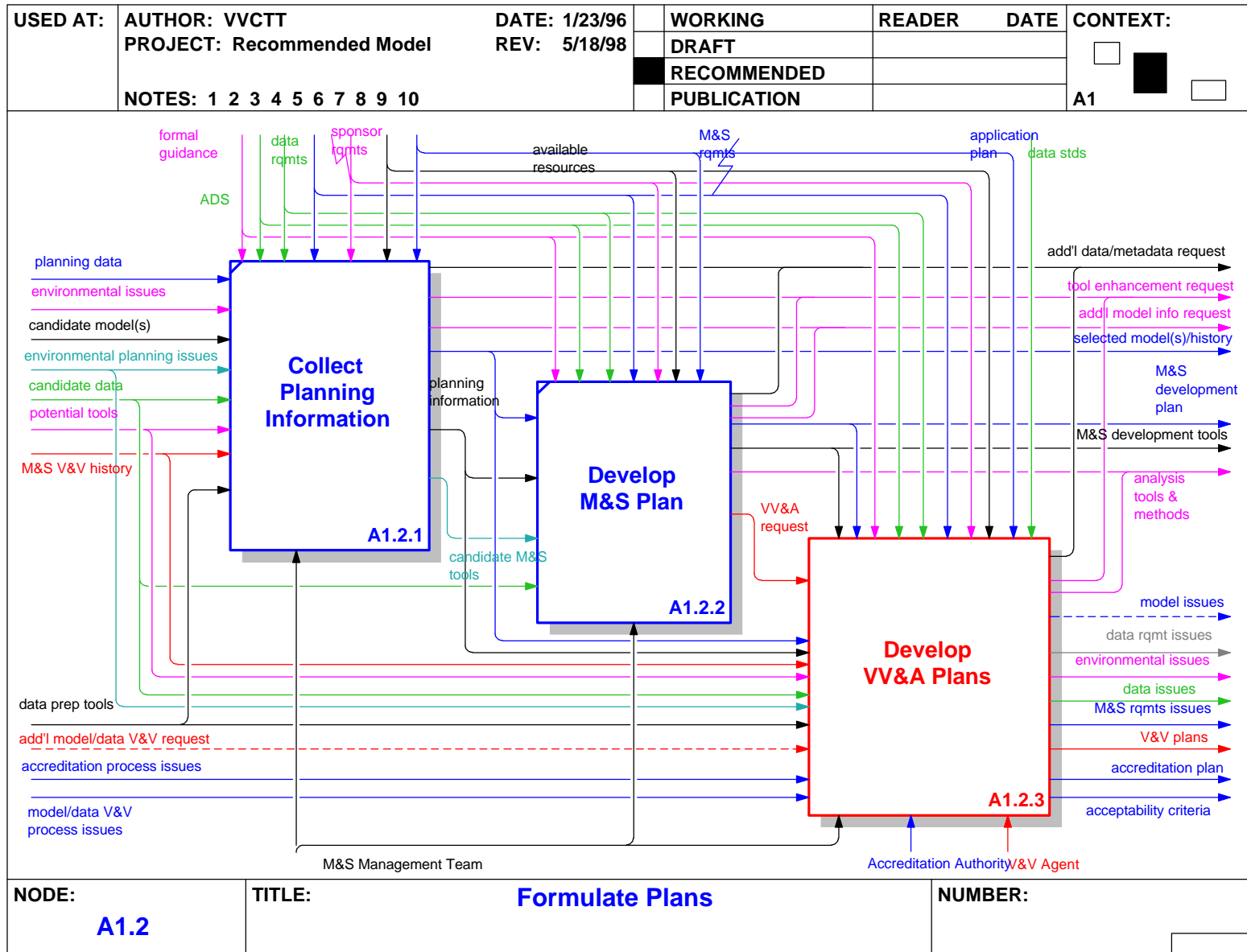
- Prepare Application
- Verify M&S for Application
- Validate M&S for Application
- Accredit M&S Application

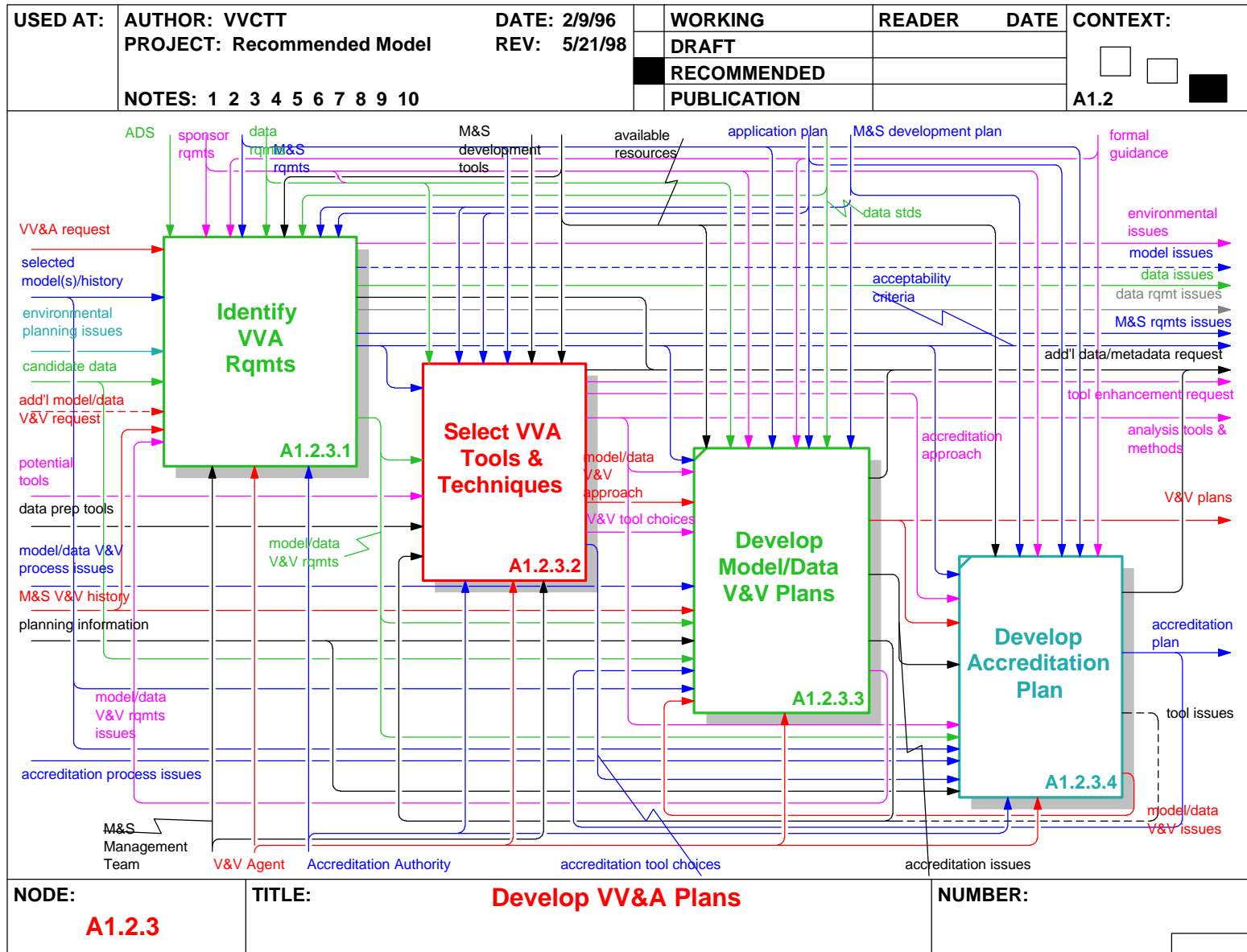
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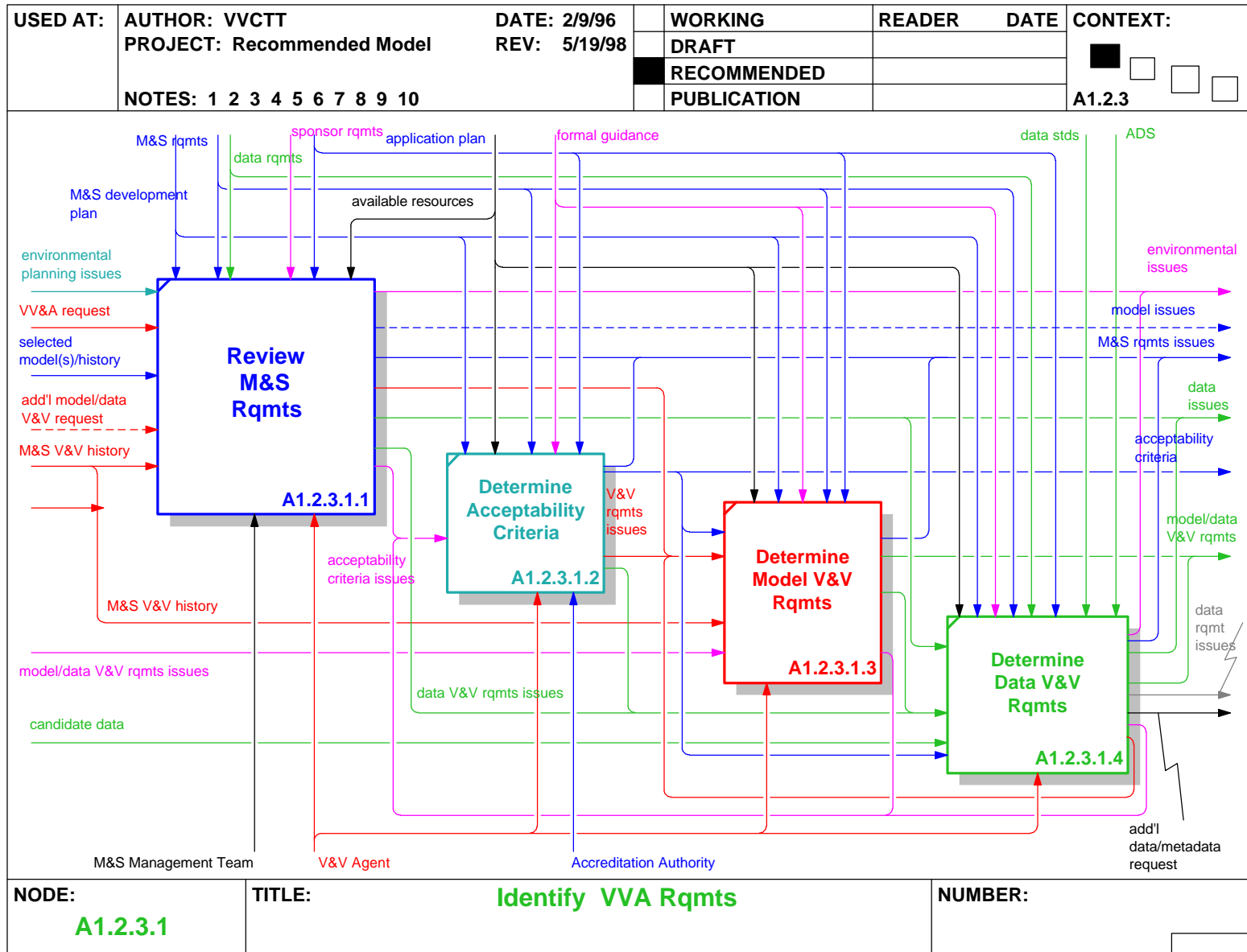


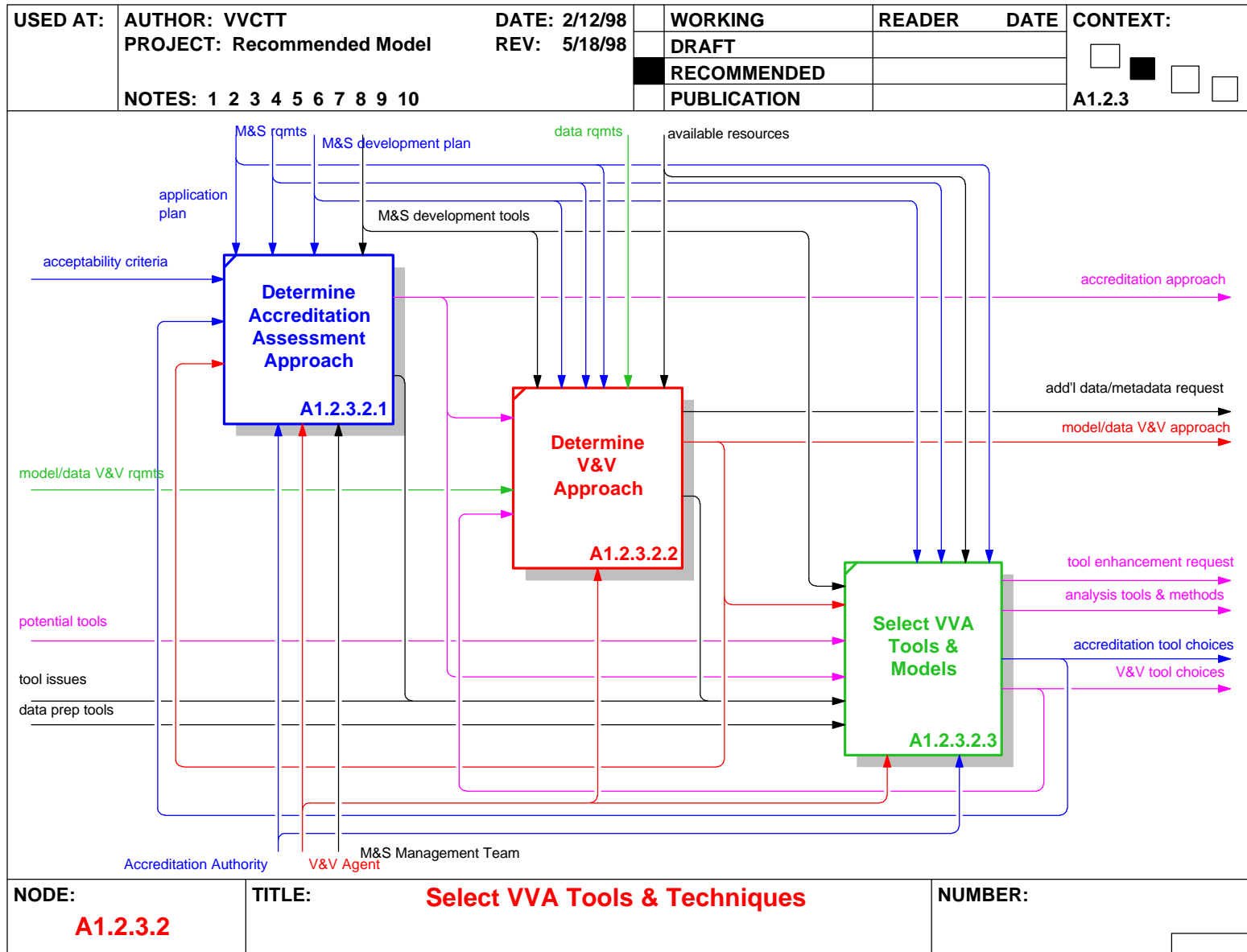


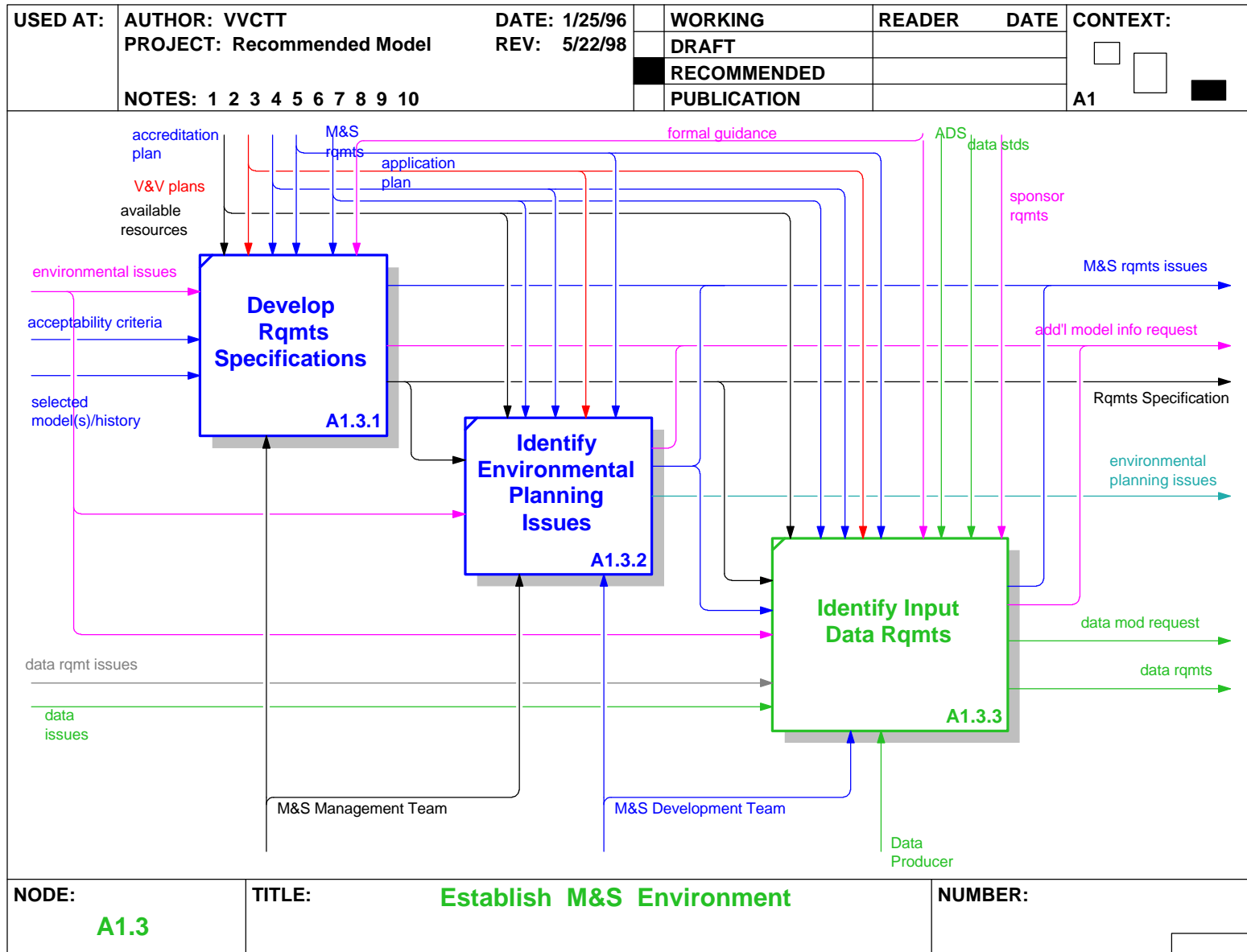


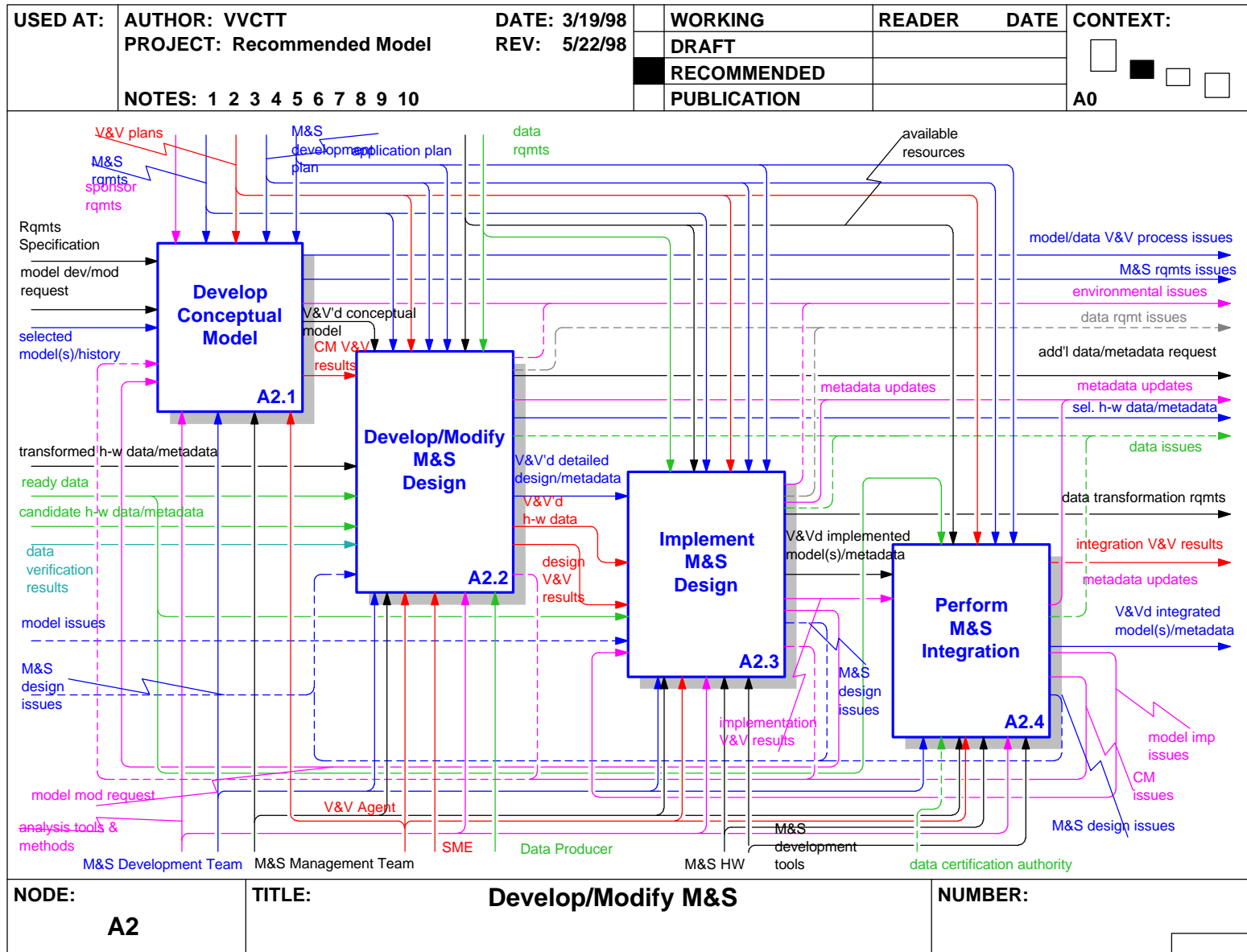


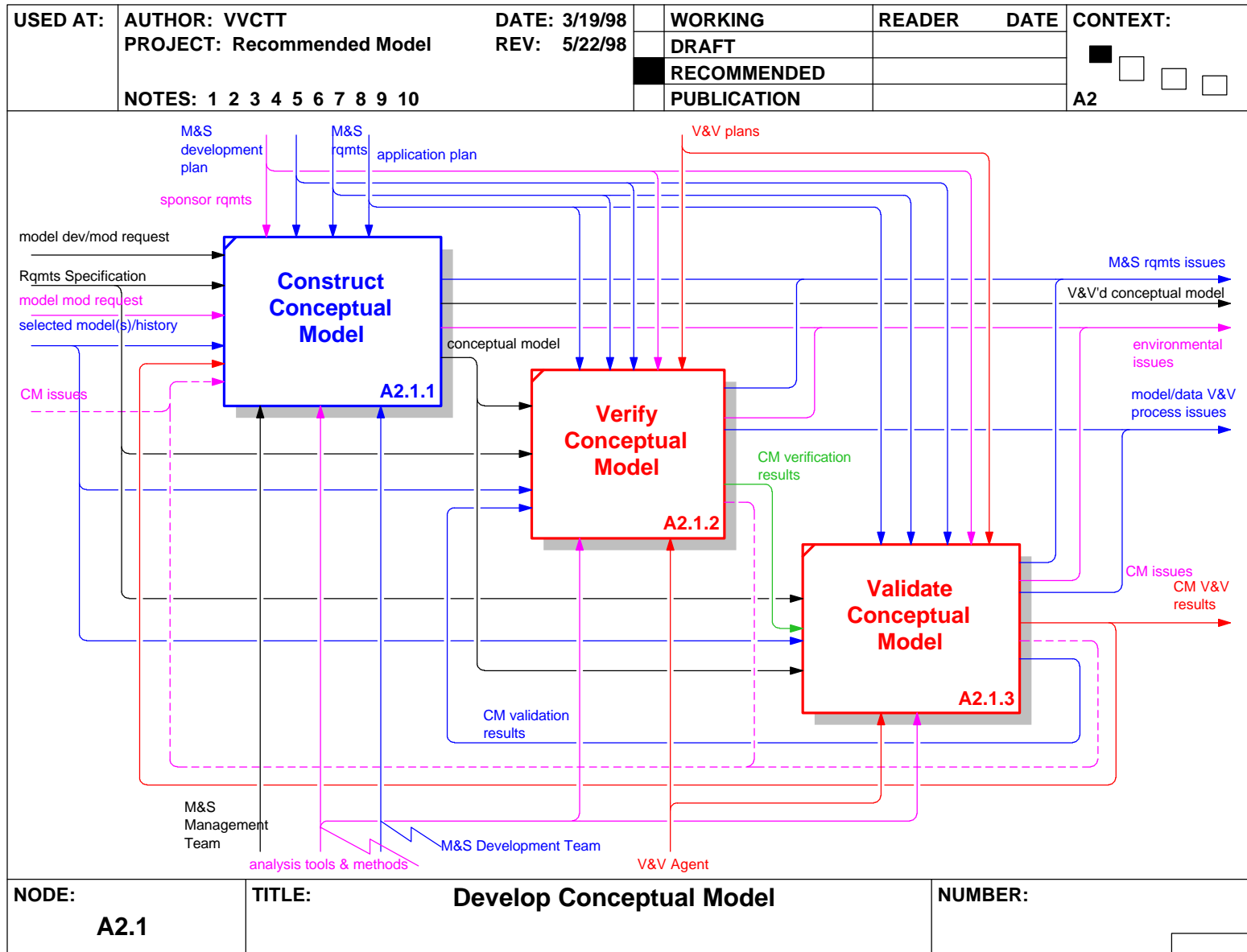


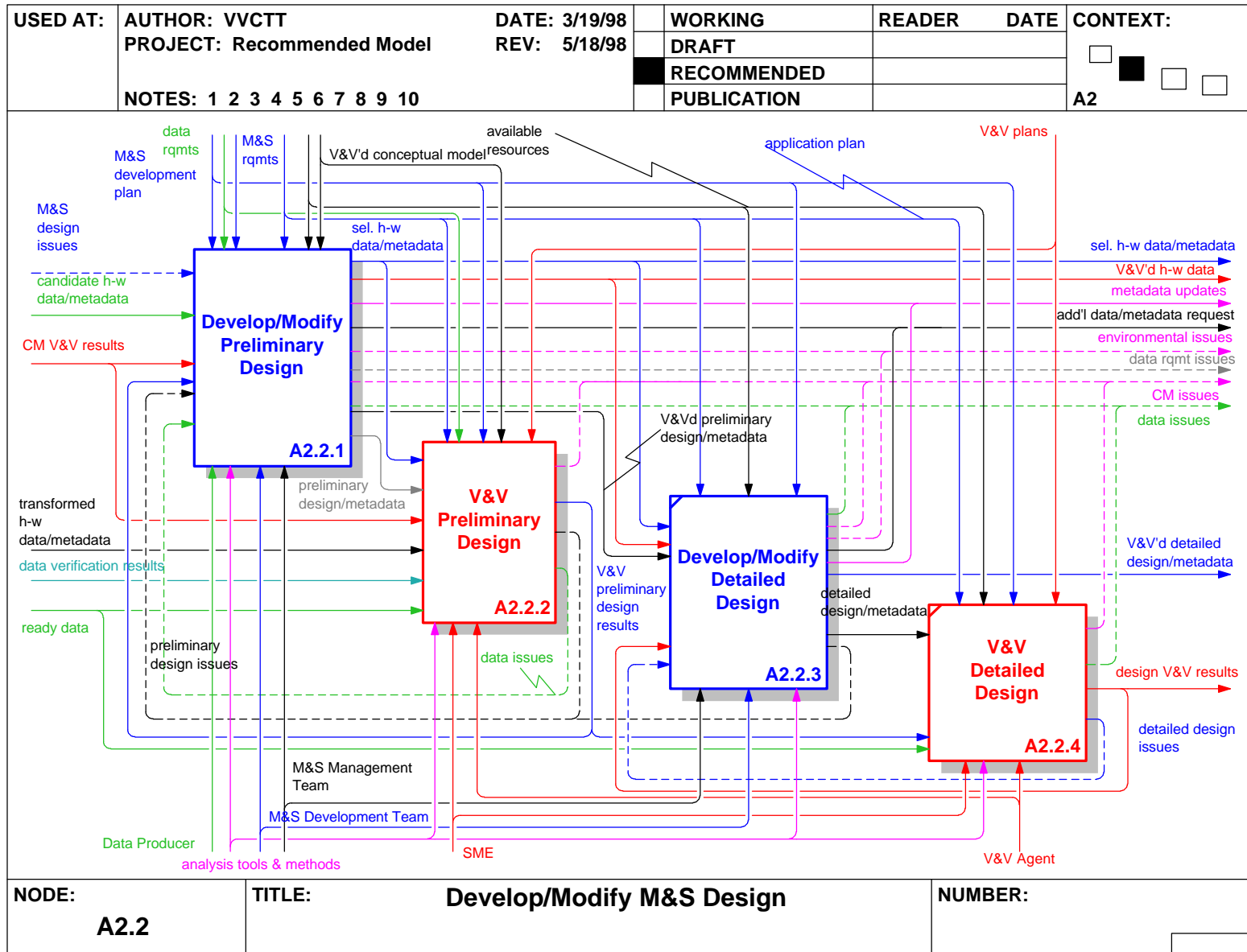


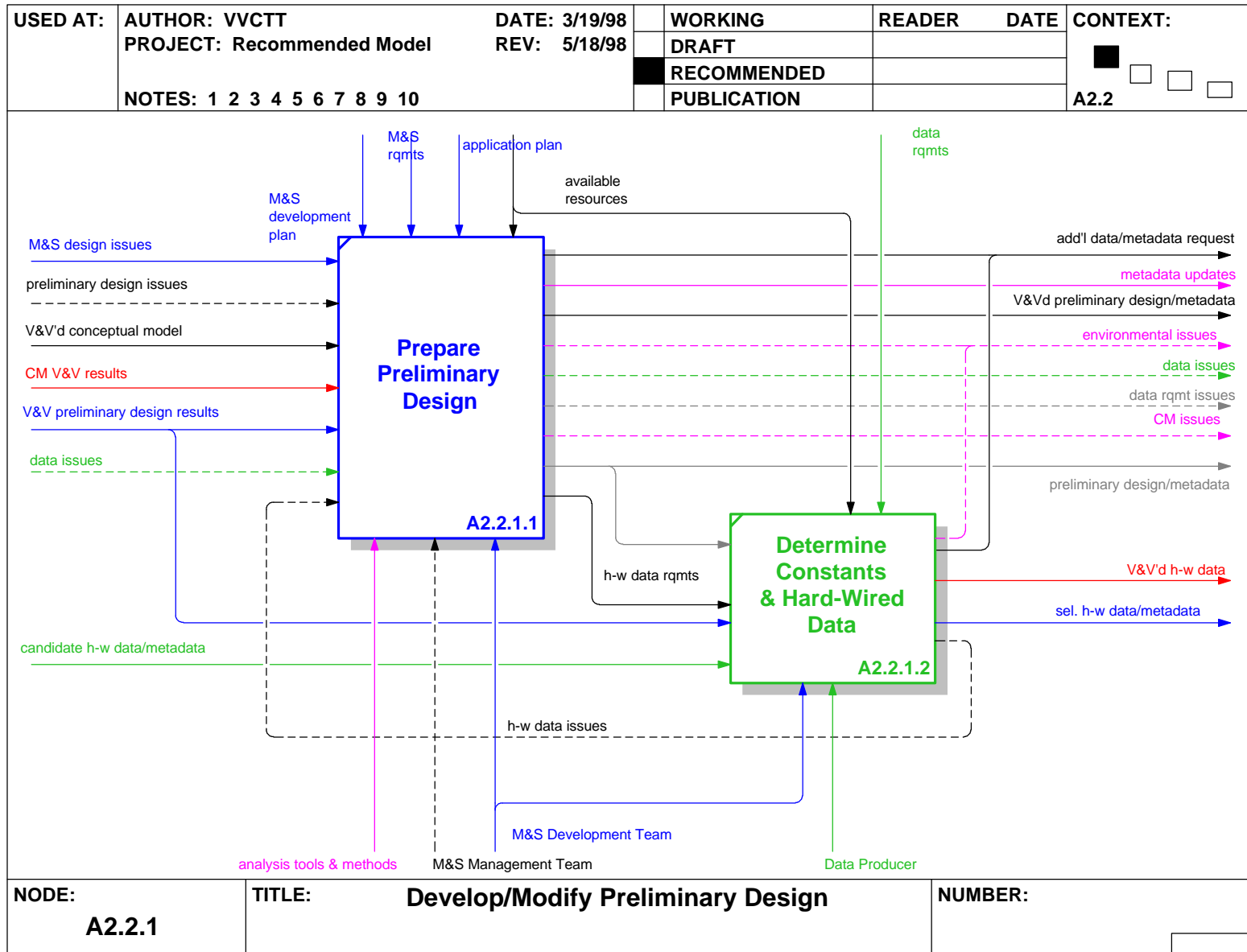


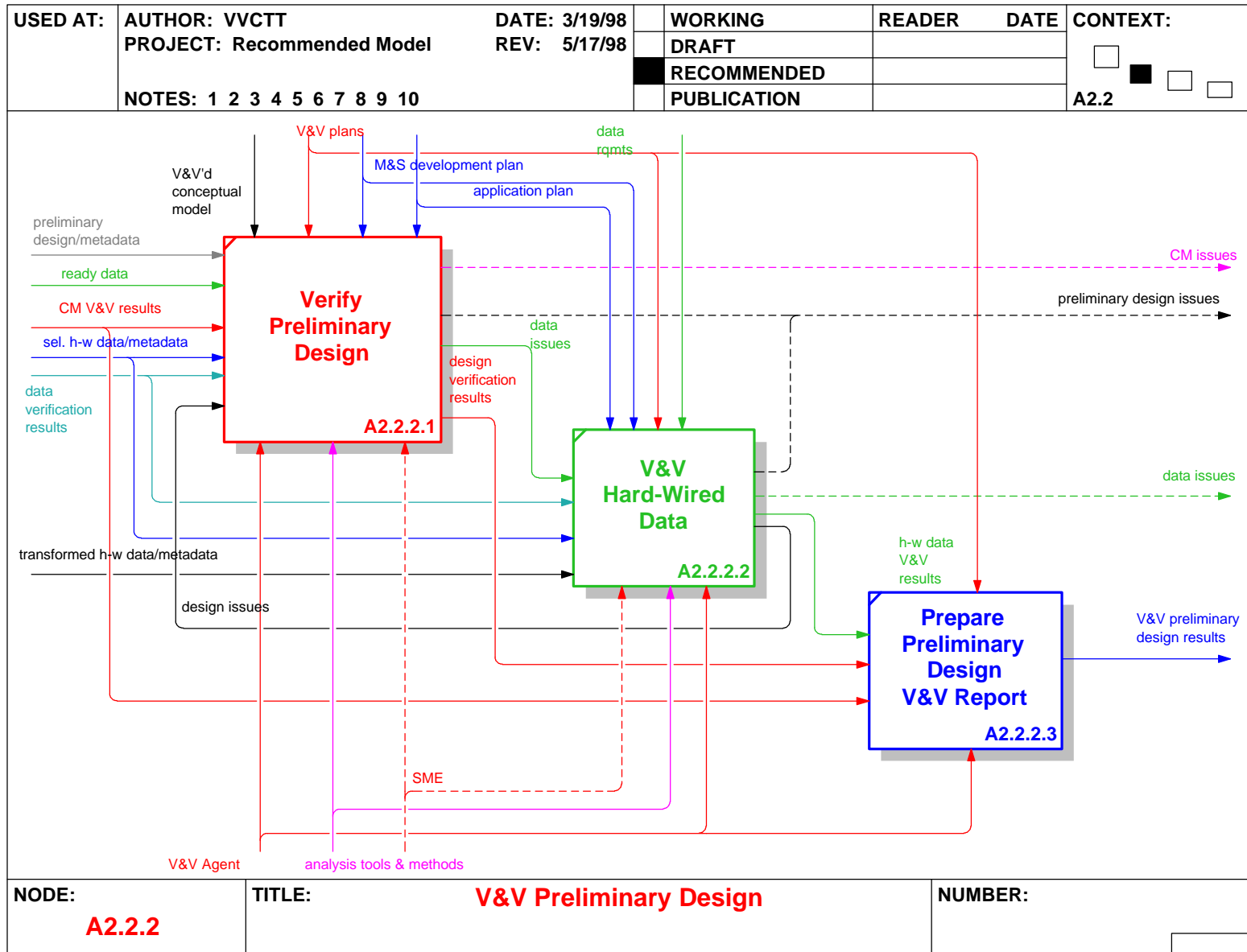


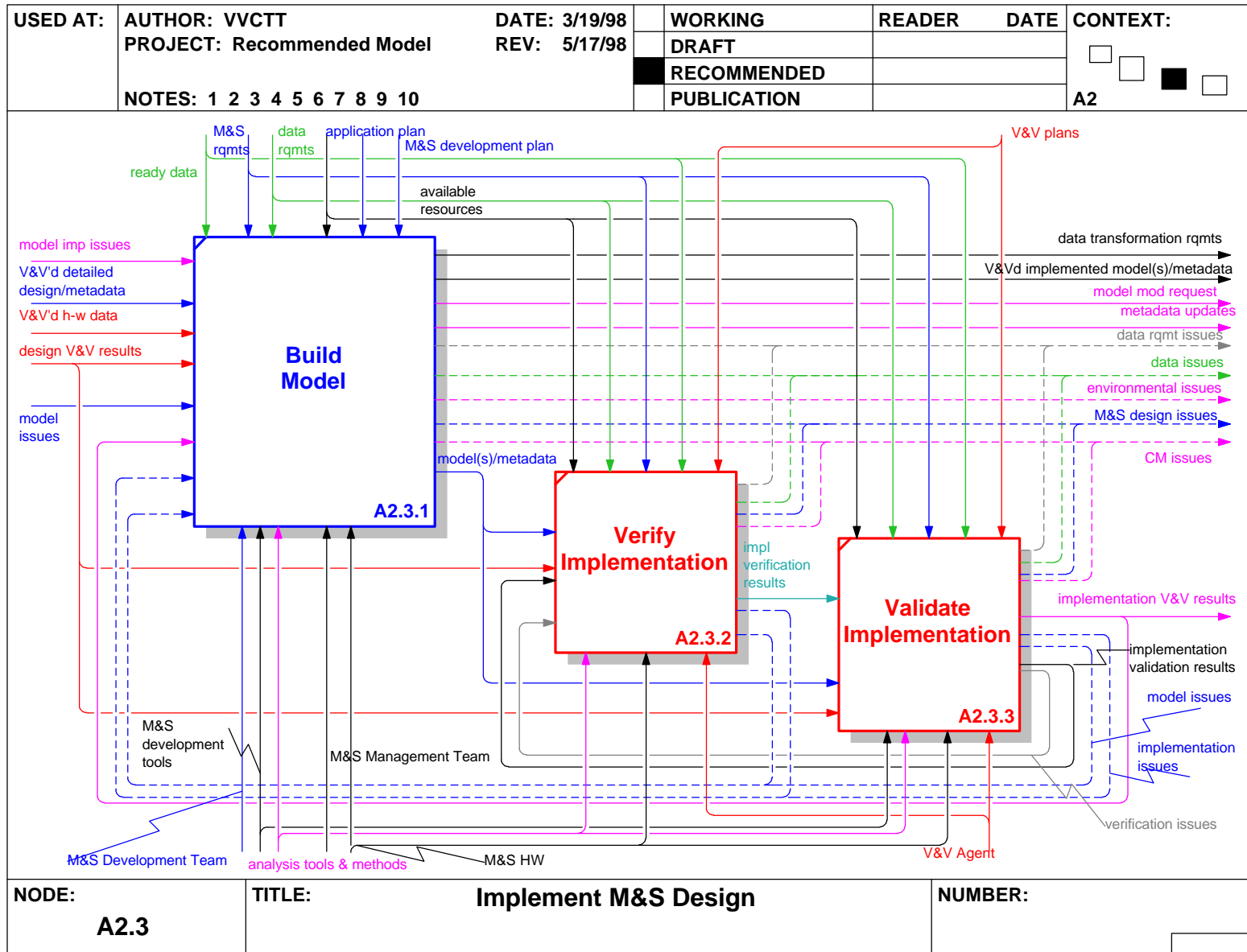


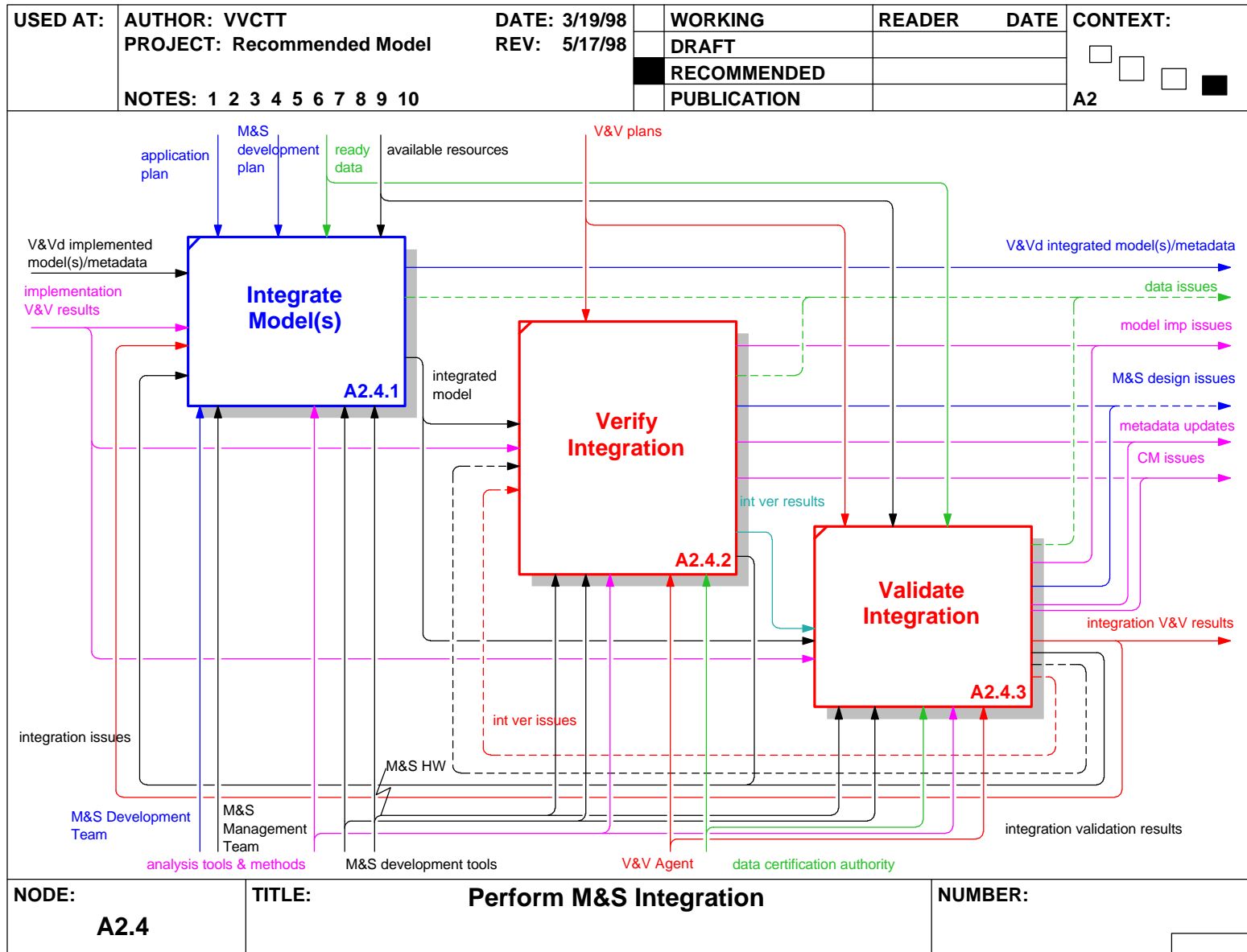


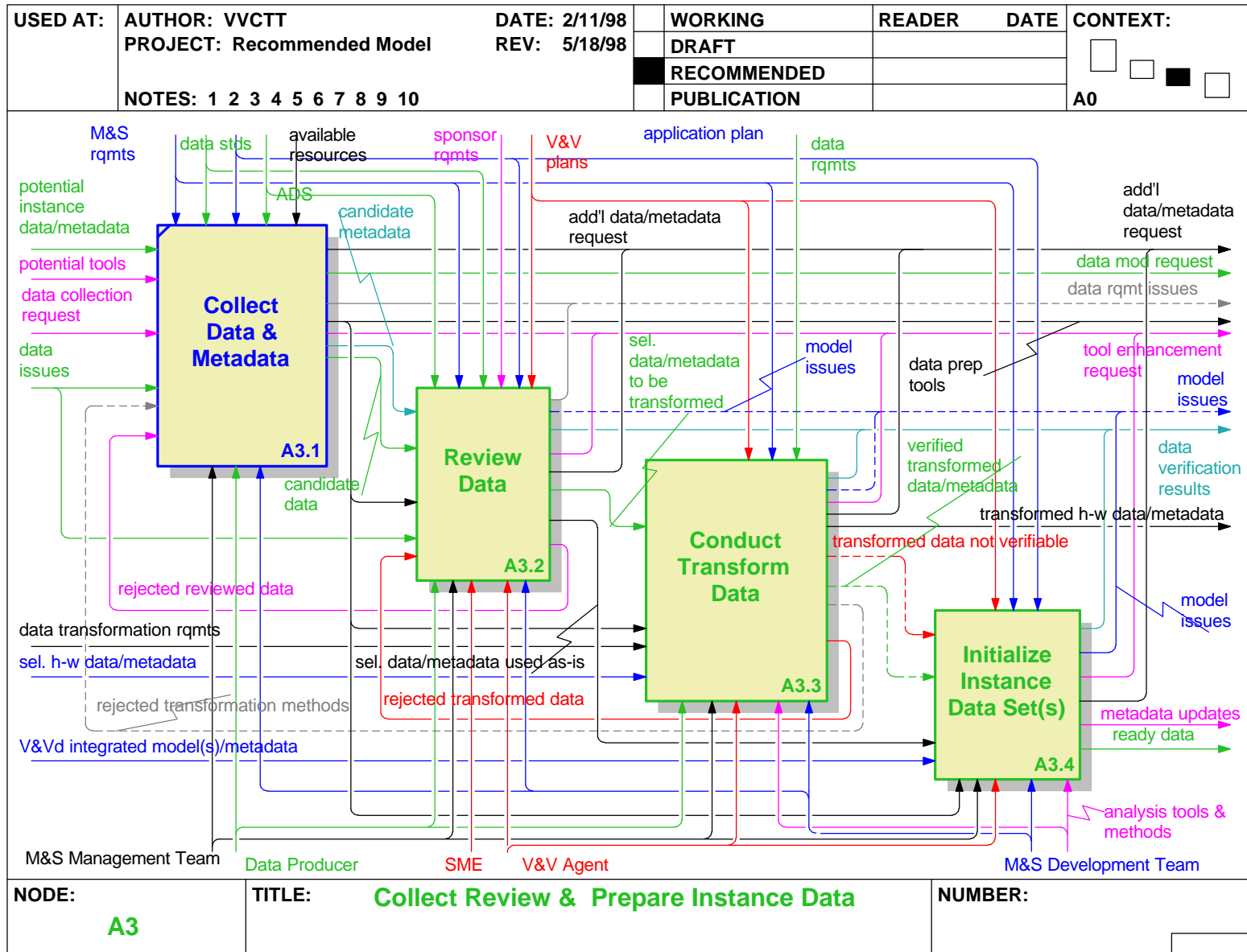


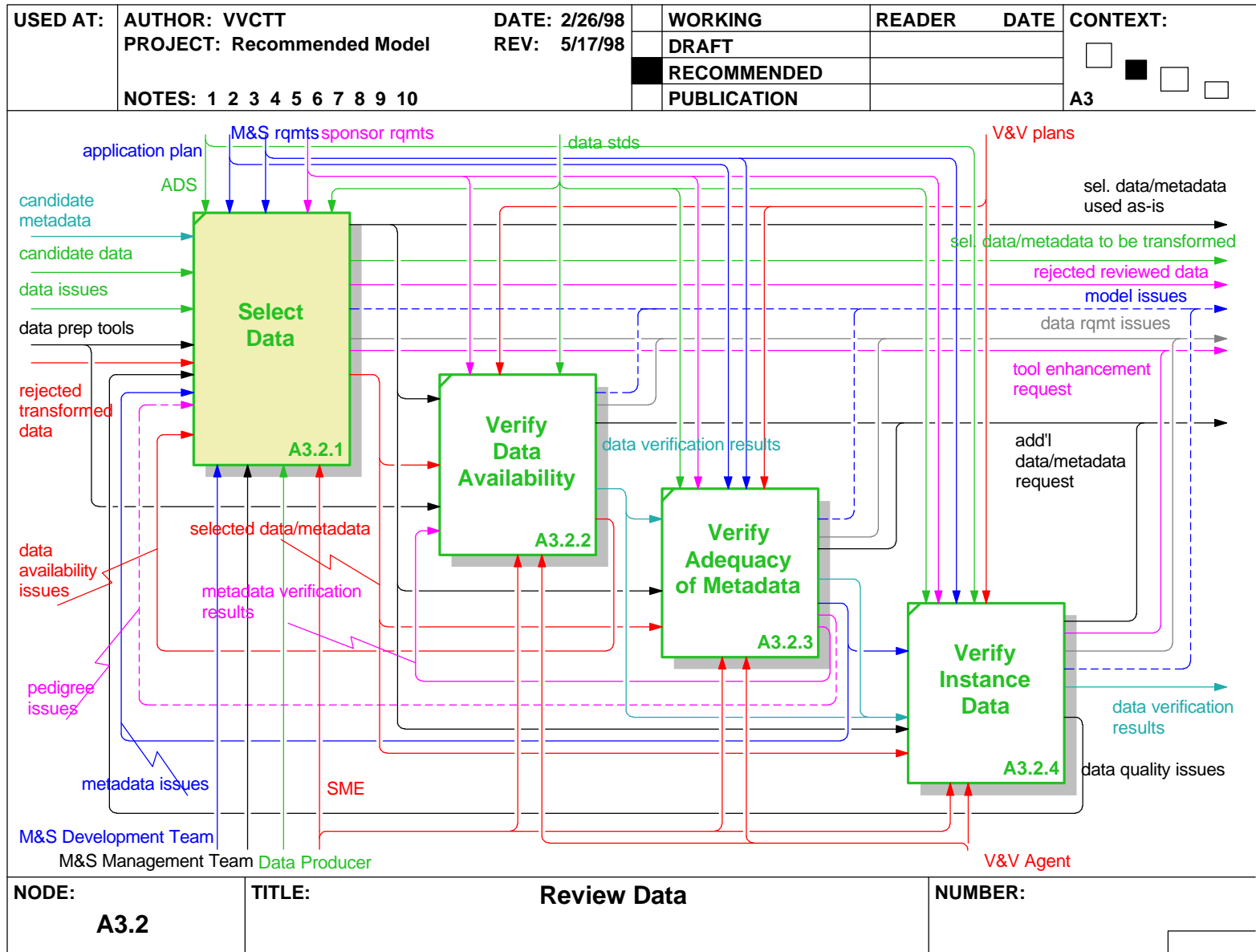


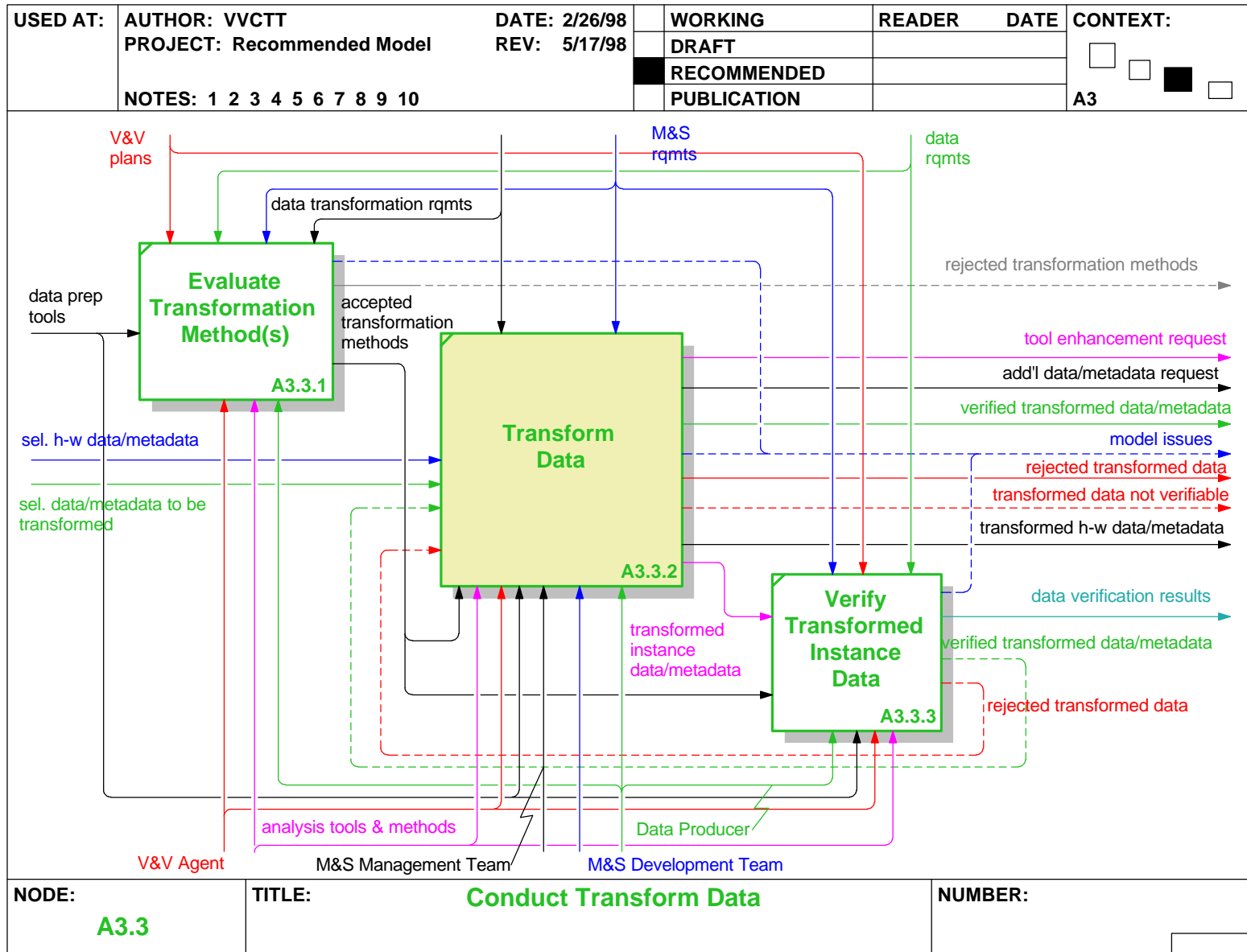


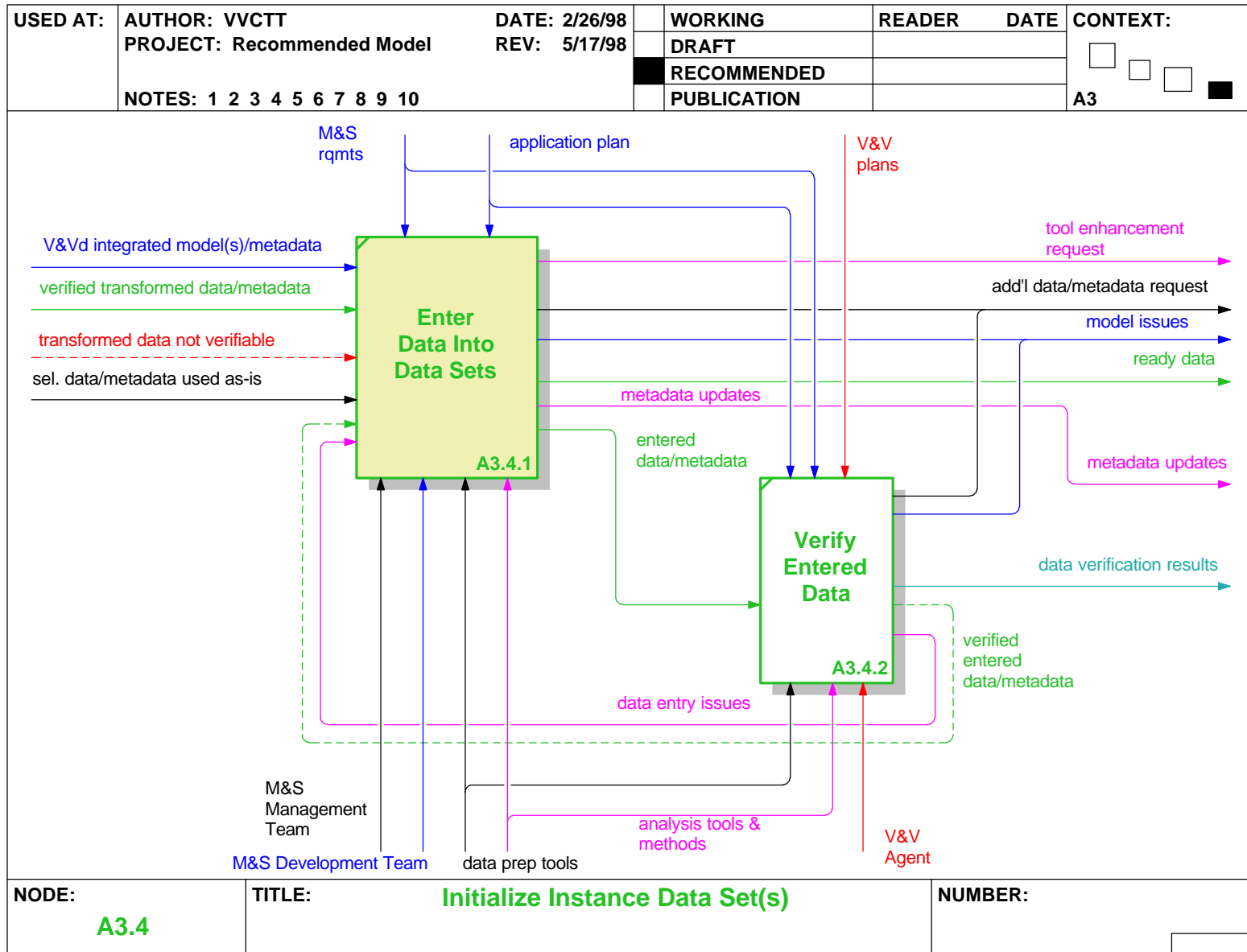


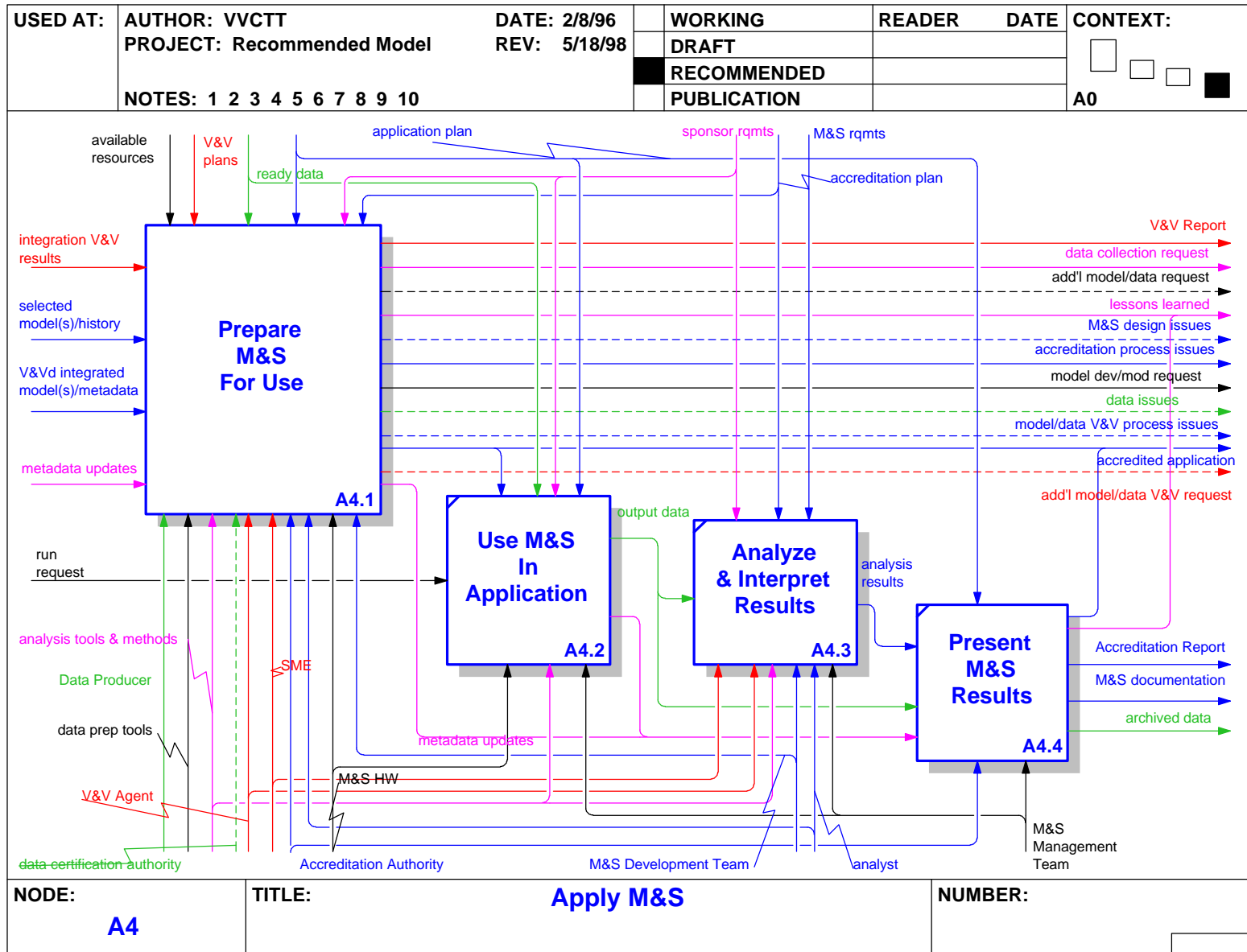


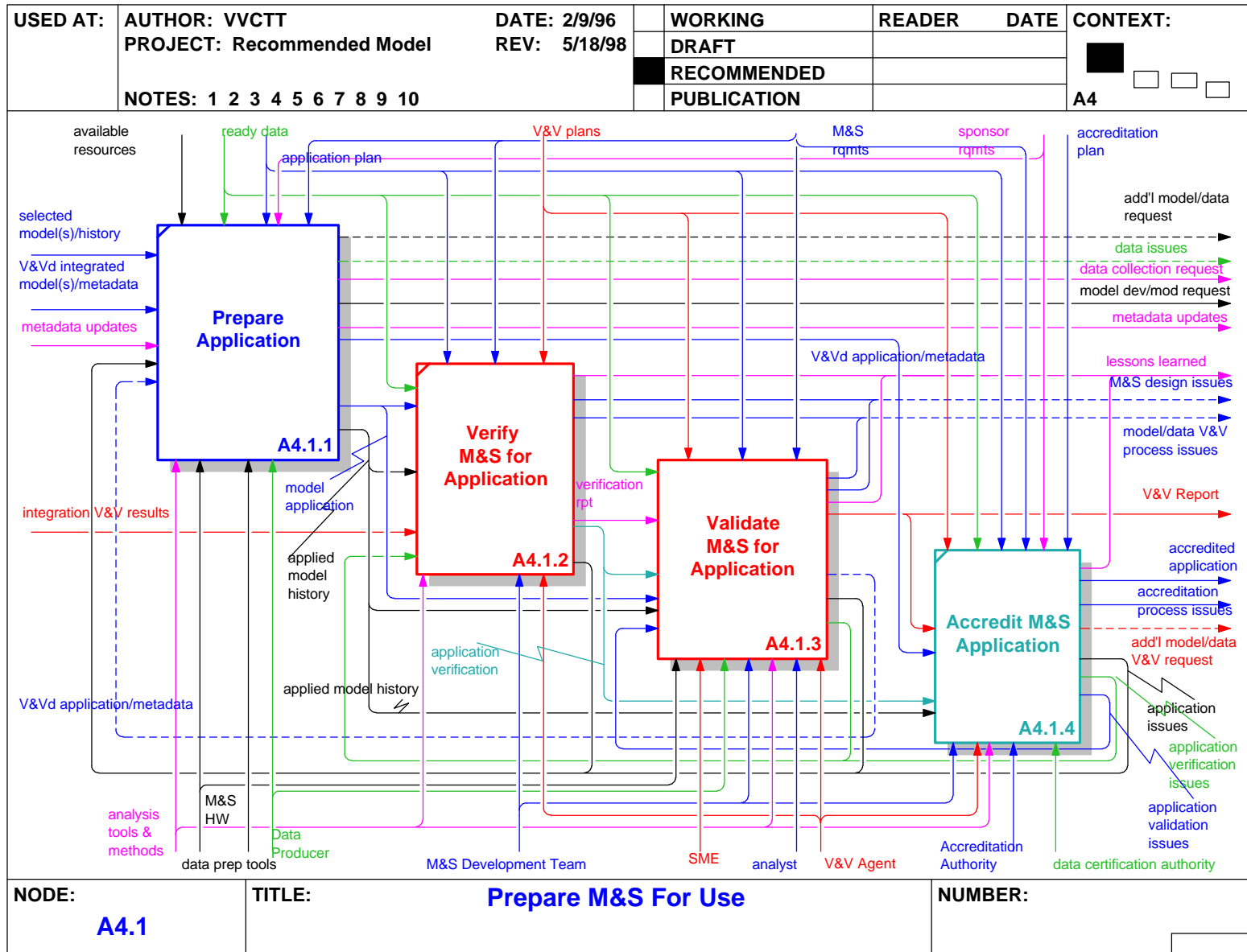


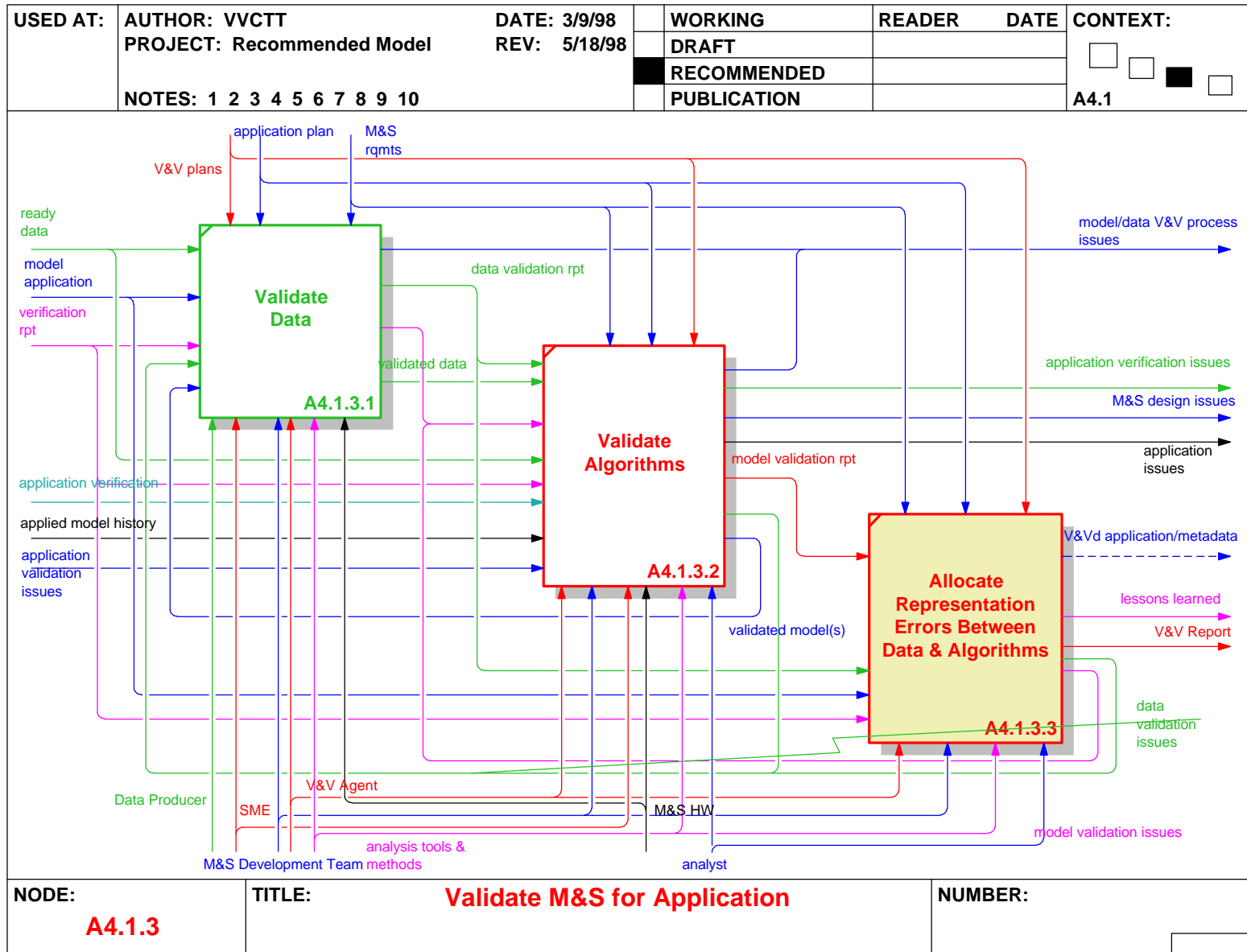












DEFINITIONS OF ACTIVITIES FOR EXECUTE M&S LIFE CYCLE PROCESS

A0 Execute M&S Life Cycle Process is the context activity for this IDEF0 model. This models the entire M&S life cycle process, including requirements definition, plan, design, develop (build/modify), integrate, implement, apply and reuse to support a defined application. The model provides for the application of existing M&S to a new purpose as well as the development of new M&S to support a class of applications.

A1 Initiate Application includes all activities preparatory to development or selection of M&S to support an application or application class.

A1.1 Identify M&S Requirements examines the requirements of the application or application class against the capabilities of existing M&S (“make vs. buy”) and either narrows the list of potential M&S to candidates which may require modification, or determines that a new M&S development is required. This activity includes identification of the application requirements that can be satisfied by the use of M&S.

A1.2 Formulate Plans is the planning activity for all aspects of M&S application, including new development or modification, testing, model and data verification and validation, M&S accreditation, and management (e.g., time and resource allocation). This activity is assumed to begin in concert with identification of requirements (A1.1) and to be the trigger for remaining life cycle activities. However, it is also assumed to be iterative in nature. Information obtained from the execution of other activities and later decisions is fed back to the planning activities so plans can be enhanced and modified to better address the evolving situation.

A1.2.1 Collect Planning Information includes the identification and collection of information needed by any or all planning activities. Although many planning activities require some unique information, much of the necessary information is required by all and such shared information must be identical (i.e., same version, same source).

A1.2.2 Develop M&S Plan includes all planning activities for the development, modification, and/or use of M&S to support a specific application or a class of applications.

A1.2.3 Develop VV&A Plans includes planning activities for verification and validation and accreditation of the M&S and its associated data for the specified application or class of applications. Each plan should focus on identifying tasks required with respect to the M&S development plan, development and application requirements, data requirements, resources and timelines. Each plan should address the requirements and constraints of the M&S application and cover critical issues, but should be flexible enough to allow adjustment, refinement, and enhancement. M&S accreditation planning is performed during this activity whether or not the accreditation is distinct from the V&V process. Instance data certification planning is included if the specific application requires it.

A1.2.3.1 Identify VVA Rqmts establishes the requirements for all V&V and accreditation activities (i.e., model and data verification and validation, M&S accreditation) based on

application requirements. The activity involves gathering and reviewing formal guidance and requirements; identifying the constraints under which model and data V&V, and M&S accreditation will operate; and, establishing criteria for the success of each.

A1.2.3.1.1 Review M&S Rqmts identifies application requirements that the existing or developmental M&S is intended to satisfy and evaluates their translation into M&S requirements resulting in recommendations for refinement and/or clarification of the requirements. For existing (legacy) M&S, requirements (constraints) established by the M&S itself are identified and assessed for impact upon the specified application program.

A1.2.3.1.2 Determine Acceptability Criteria involves identification of the factors to be evaluated (e.g., representational, performance, functional, operational) and determination of measures and limits (e.g., levels of divergence, deviations) that characterize acceptable performance based on the requirements of the application.

A1.2.3.1.3 Determine Model V&V Rqmts establishes the model or component verification and validation requirements based on M&S requirements and acceptability criteria.

A1.2.3.1.4 Determine Data V&V Rqmts establishes data verification and validation requirements for hard-wired data, instance data, and independent validation data and identifies data certification requirements when necessary for the specified application.

A1.2.3.2 Select VVA Tools & Techniques determines general approaches for model and data verification, validation and accreditation and identifies appropriate tools, techniques, methods, and models to support each effort.

A1.2.3.2.1 Determine Accreditation Assessment Approach establishes the means to evaluate M&S capabilities and assess risks to establish accreditation for the specified application based on the results of V&V activities, testing, and additional external factors.

A1.2.3.2.2 Determine V&V Approach identifies the model and data verification and validation activities most suitable to support the accreditation decision.

A1.2.3.2.3 Select VVA Tools & Models selects from the set of prospective tools, techniques, procedures, methods, and models those that are deemed most appropriate to support individual V&V and accreditation activities.

A1.2.3.3 Develop Model/Data V&V Plan(s) develops V&V plans as drafts or working documents that are expected to evolve as the application takes shape (e.g., when new information is available, when changes in requirements, resources, etc., occur).

A1.2.3.4 Develop Accreditation Plan develops the accreditation plan as a draft or working document which is then modified/updated whenever changes in requirements, resources, etc. occur that impact the acceptability of the application.

A1.3 Establish M&S Environment defines the environment needed to support the M&S in the specified application or application class.

A1.3.1 Develop Rqmts Specifications involves the articulation of requirements specifications for the development or modification of an M&S for a specific application or application class. Requirements specifications are based on the requirements of the application, derived specifications of the M&S technology chosen, and external constraints such as resource availability, data requirements, and timelines.

A1.3.2 Identify Environmental Planning Issues identifies issues related to the establishment of an appropriate M&S execution environment.

A1.3.3 Identify Input Data Rqmts defines the types of data required to execute the M&S in the specified application and describes the constraints that the M&S imposes on the data to be used (e.g., instance data (data contained within a database) or hard-wired data (constants and data compiled with the code)). Data requirements are used to narrow the search for data sources and evaluate the quality of data provided.

A2 Develop/Modify M&S comprises all activities required to develop either a new M&S for a specific application or class of applications, or to modify the code and/or structure of an existing M&S for the purpose of extending the range of applications that it can validly support.

A2.1 Develop Conceptual Model involves the set of activities resulting in the creation and evaluation of the conceptual model. The conceptual model is a representation of the M&S developer's understanding of the objectives, requirements and environment. It serves as a vehicle for transforming requirements into functional and behavioral capabilities and provides a crucial traceability link between the sponsor's requirements and the design implementation.

A2.1.1 Construct Conceptual Model is done by the M&S designers or developers and results in a theoretical model that is suited to support the application requiring the M&S. The conceptual model serves to clarify through abstraction the specific requirements and features that the completed M&S will exhibit; it is implementation-independent.

A2.1.2 Verify Conceptual Model assesses the conceptual model against the application requirements in order to assure that all requirements have been addressed (and that extraneous requirements or "nice-to-have's" are not). The underlying logic of the conceptual design is traced to identify dynamic issues relating to the physical and behavioral representations.

A2.1.3 Validate Conceptual Model assesses the conceptual model's suitability for the intended application, ensuring it adequately specifies both physical and behavioral aspects of the application domain and that operational requirements are traceable in the emerging design.

A2.2 Develop/Modify M&S Design is that set of activities resulting in delivery of a new or modified M&S in the form required for the specified application. In the context of primary interest, this form is generally a computer program implementing the conceptual model. Model

design is an iterative process in which details and specificity are added and evaluated at each iteration. The early iterations are considered “preliminary,” later ones, “detailed.”

A2.2.1 Develop/Modify Preliminary Design allocates the model requirements derived from the conceptual model in hardware configuration items and software configuration items and identifies requirements for, locates and collects hard-wired data.

A2.2.1.1 Prepare Preliminary Design allocates the requirements and documents that allocation.

A2.2.1.2 Determine Constants & Hardwired Data identifies data that should be implemented as part of the model’s code (e.g., compiled) rather than accessed from external databases or files. This activity also identifies appropriate data sources and collects and/or generates the data.

A2.2.2 V&V Preliminary Design includes verification and validation activities on the preliminary M&S design and data requirements.

A2.2.2.1 Verify Preliminary Design ensures that all features/functions/behaviors of the preliminary design can be traced back to a requirement expressed through the conceptual model, and that all requirements expressed through the conceptual model can be traced to either a hardware or software configuration item.

A2.2.2.2 V&V Hardwired Data verifies that constants and hard-wired data obtained from data sources have been documented in their original form and the data, when transformed into the form required for use in the M&S, is valid for its intended purpose and any deviations from validity criteria are corrected or at least documented.

A2.2.2.3 Prepare Preliminary Design V&V Report results in documentation of that portion of the report on M&S and data verification and validation findings pertaining to the preliminary design. These findings should be recorded as a formal part of the record of M&S development and should be a configuration control document.

A2.2.3 Develop/Modify Detailed Design completes the design of the M&S by allocating requirements to computer software components, defining and documenting the interfaces among the components and with external systems, detailing the design and structure of the data bases, and identifying authoritative sources for all required data.

A2.2.4 V&V Detailed Design traces all requirements and derived requirements to the software components of the design, and assures that all features and capabilities of the software components are traced to requirements.

A2.3 Implement M&S comprises activities supporting the realization of the M&S design in program code and actual hardware using real data. On completion of the implementation activities, components/modules of the M&S can be executed and tested.

A2.3.1 Build Model translates the design into code and tests the code at the unit

(component/module) level.

A2.3.2 Verify Implementation traces requirements to implemented software components and reviews code.

A2.3.3 Validate Implementation investigates the extent to which the requirements are satisfied by the individual components/modules.

A2.4 Perform M&S Integration includes the activities required to integrate the components/modules and complete the development/modification of the M&S.

A2.4.1 Integrate Model(s) assembles the software components/modules into a cohesive whole, tests the assemblies, provides initial training in the use of the M&S, prepares the M&S for delivery, and provides for acceptance testing/demonstration of the M&S.

A2.4.2 Verify Integration traces all requirements through the conceptual model and design to the completed M&S.

A2.4.3 Validate Integration investigates the extent to which the M&S (as built, together with its instance data) represents the real world. For a large scale M&S being developed for general use, the validation investigates its representation of the real world over the entire range of conditions for which the M&S was developed.

A3 Collect, Review & Prepare Instance Data includes all activities required to obtain and prepare instance data (i.e., data used to drive the M&S during execution).

A3.1 Collect Data & Metadata includes those activities required to obtain appropriate data (and its associated metadata) that will be usable (as-is or transformed) to serve as instance data for the M&S. Data sources and databases are selected. Corresponding metadata are gathered. Additional data and metadata are sought. Potential tools (e.g., those used in data production) and tools selected for use in model development and analysis are examined and tools appropriate for data preparation/transformation are selected.

A3.2 Review Data checks the appropriateness of data sources to ensure they are authoritative; reviews data sets/bases for completeness (e.g., data voids, missing categories), appropriateness (data quality) and availability (security restrictions, actual existence); and checks adequacy of data preparation tools for use in data V&V.

A3.2.1 Select Data reviews candidate data and categorizes as “selected data to be used as-is,” “selected data to be transformed,” and “rejected reviewed data.”

A3.2.2 Verify Data Availability determines if the selected data and associated metadata are available and ensures the data sets are complete (no voids), available at the appropriate classification, and accessible for use by the M&S in the specified application.

A3.2.3 Verify Adequacy of Metadata ensures that the metadata associated with all required data are sufficient to completely characterize the data in the context of the current application. Examines and verifies the pedigree (e.g., data source) of selected data.

A3.2.4 Verify Instance Data examines and verifies the appropriateness of the quality of the selected data for the specified application.

A3.3 Conduct Transform Data evaluates and applies algorithms and other methods to change the form of the data to one that is directly useable by the M&S and verifies the resulting data.

A3.3.2 Transform Data accepts instance data as obtained from a data source and yields data ready for entry into the M&S. In some cases, the transformation algorithms and processes may incorporate data entry procedures.

A3.3.1 Evaluate Transformation Methods investigates whether the algorithm or process used to perform the transformation will yield valid, substantially equivalent data. This activity does NOT specifically investigate the validity of the instance data, merely what is done to it. In general, this activity is conducted only during the development phase of M&S or when new authoritative data sources have been selected.

A3.3.3 Verify Transformed Instance Data assures that data are transformed according to the expectations of the transformation for all elements of the instance data in the transformation's input set. Note that data producers may act as SMEs.

A3.4 Initialize Instance Data Set(s) consists of those activities needed to make the data accessible to the M&S.

A3.4.1 Enter Data Into Data Sets is the activity during which data are entered into the M&S. For changeable instance data, this activity involves entering data into databases, flat files, or other mechanisms to make it accessible to the M&S at run time. For hard-wired data this is the process of preparing and compiling the data parts of the M&S's source language (e.g., DATA statements in FORTRAN, or constants coded into equations or source language statements). The hard-wired data process is conducted in conjunction with M&S design and modification activities.

A3.4.2 Verify Entered Data assures that the instance data entered for use by the M&S is that which was intended to be entered. Hard-wired data are verified in conjunction with M&S design/modification V&V activities.

A4 Apply M&S comprises all activities required to use M&S in support of system acquisition, training, test and evaluation, analysis, research and development, or any other application. The activities are appropriate for the first or the nth use of an M&S package.

A4.1 Prepare M&S for Use performs those functions required on the selected M&S to make it ready for use.

A4.1.1 Prepare Application tailors the selected M&S to the specific application, assembles participants (including operator-in-the-loop personnel), and conducts tests and rehearsals.

A4.1.2 Verify M&S for Application maps application requirements to the selected M&S to ensure all are addressed.

A4.1.3 Validate M&S for Application investigates the extent to which the M&S represents the real world as required for the application. Validation of the data and of the algorithms are inextricably intertwined, may be conducted simultaneously in some cases, and may differ only in the role assigned to the M&S (the subject when validating the algorithms; a tool, when validating the instance data).

A4.1.3.1 Validate Data investigates the extent to which the instance data set contributes to appropriate response of the M&S in the context of the current application requirements.

A4.1.3.2 Validate Algorithms investigates the extent to which the M&S, driven by valid instance data sets, provides appropriate responses when exercised in the context of the current application requirements.

A4.1.3.3 Allocate Representation Errors Between Data & Algorithms evaluates the discrepancies between M&S responses and real-world behaviors and attributes them to errors in data or M&S algorithms. For example, if a “cookie cutter “ radar model is used in a particular application, the errors of the radar’s probability of detection can be allocated as a function of target range between (a) the simple binary characteristic of the cookie cutter model, and (b) the radius of the cookie cutter. The errors can be reduced either by choosing a more elaborate algorithm, by adjusting the detection radius of the cookie cutter model, or both.

A4.1.4 Accredit M&S for Application assesses the risks associated with deviations from validity on the purpose for using the M&S and the impact of external constraints (e.g., resources, time) and presents the assessment to the accrediting authority who determines whether the risks and conditions are acceptable. If so, the accrediting authority accredits the use of the M&S for the specific purpose defined by the application requirements.

A4.2 Use M&S in Application includes all activities associated with using the M&S to support the application.

A4.3 Analyze & Interpret M&S Results includes all activities involved in evaluating the performance of the M&S and its results in the specified application.

A4.4 Present M&S Results prepares and presents the results to the decision-makers.

DEFINITIONS OF ICOMS FOR EXECUTE M&S LIFE CYCLE PROCESS

acceptability criteria	M&S capabilities needed to address the requirements appropriately. Should be applied at initial M&S selection as well as during the acceptability assessment.
acceptability criteria issues	questions regarding acceptability criteria that arise during the development of V&V requirements and plans
accepted transformation methods	Tools, algorithms, etc. chosen to prepare data for use in the model. Includes preparation of instance data and hard-wired data (e.g., constants).
accreditation approach	Method(s) used in the accreditation assessment. Should include a list of activities and information requirements needed to address each of the acceptability criteria.
Accreditation Authority	Person or agency designated by Sponsor to accredit the current application of the M&S.
accreditation issues	Questions pertaining to the accreditation plan (e.g., procedures, schedule, resources) identified during development of the V&V plan.
accreditation plan	Detailed plan for accreditation of the current M&S application. Developed in conjunction with model and data V&V and M&S Development plans for same.
accreditation process issues	Questions pertaining to the accreditation process (e.g., adequacy, relevance) raised during the assessment.
Accreditation Report	Final report documenting the rationale and results of the accreditation process.
accreditation tool choices	Tools, techniques, models, etc. used in the accreditation assessment.
accredited application	The M&S as used to support a specific application.
add'l data/metadata request	Requests made for additional data and/or additional information (e.g., metadata) regarding data under consideration for use.
add'l model info request	Requests for additional or amplified information about one or more of the models under consideration for use (i.e., potential models).
add'l model/data request	Request for additional models and/or data.
add'l model/data V&V request	Request to perform additional verification and/or validation upon a model, group of models, or parts of a model and/or the associated data.
ADS	Authoritative Data Source Repository or list of data sources and pedigrees

analysis results	Results of analyzing the use of M&S in a specific application (or class of applications) and the data resulting from that use.
analysis tools & methods	The collection of tools, methods, techniques, models, etc., used to conduct model and/or data V&V and accreditation, as well as those used in the analysis of M&S output /results. Can include data preparation tools, M&S development tools, M&S HW.
analyst	Those responsible for conducting evaluation of M&S performance and/or its resulting data.
application issues	Concerns identified during V&V that pertain to the appropriateness of the M&S and/or data for the stated purpose.
application plan	The plan developed to support the problem statement that documents all relevant planning information for the development and/or use of the M&S supporting the specific application. Note that this plan precedes the application trigger (Problem Statement).
application validation issues	Concerns raised during the accreditation process that pertain to validation of the application.
application verification	Results of the process verifying the M&S application.
application verification issues	Concerns raised during the accreditation process that pertain to verification of the application.
applied model history	Documentation about the M&S that pertains to the application.
archived data	All data related to the M&S life cycle that are deemed to have future value.
available resources	Resources set aside for use in the development, modification, and preparation of the M&S for the application. Includes resources for testing, verification, and validation of the model(s) and data involved.
candidate data	Potential data being considered for use in the application of the M&S.
candidate h-w data/metadata	Hard-wired data (e.g., constants) and its associated metadata being considered for use in the model(s) being developed or modified.
candidate M&S tools	Tools, techniques, etc., being considered for use during M&S development, modification, and/or testing.
candidate metadata	Metadata (information) about data candidates.
candidate model(s)	M&S or components identified from the set of prospective M&S that appear to be suitable to support the application.

CM issues	Issues related to the definition, development, verification, or validation of the conceptual model.
CM V&V results	Results of performing verification and validation of the conceptual model.
CM validation results	Results of performing validation of the conceptual model.
CM verification results	Results of performing verification of the conceptual model.
conceptual model	The representation of the M&S required by the application, which describes the functional, physical, representational, and performance requirements and their interrelationships.
data availability issues	Issues identified related to the availability or non-availability of instance data required to support the M&S.
data certification authority	Optional. The person or agency (if any) designated by Sponsor to certify data for use in the given application. Different authorities may be designated for different data types.
data collection request	A request initiated by the Apply Data activity to obtain instance data required to support the execution of the M&S.
data entry issues	Issues identified related to the population of data sets with instance data required to support the M&S.
data issues	Issues specifically related to the instance data being considered to support the application.
data mod request	Request to an external agency (usually a data producer) to modify its product, or elements of its data product to make it more suitable for the intended use.
data prep tools	Tools, techniques, and procedures used in the preparation of instance data for use in the M&S. (Becomes a subset of analysis tools and methods when selected for use in the data V&V process.)
Data Producer	Person and/or agency responsible for development of data and for its quality assessment.
data quality issues	Issues pertaining to the quality of the instance data and its appropriateness for use in the specified application.
data rqmt issues	Issues specifically related to the stated data requirements.
data rqmts	Specific requirements related to any and all data needed during the M&S life cycle.
data stds	Policies and technical standards governing instance data sets intended for use in the development of the M&S and/or in the specified application.

data transformation rqmts	Requirements imposed on data format and/or fidelity by the M&S or the application.
data V&V rqmts issues	Issues related to the verification and/or validation requirements for data.
data validation issues	Issues related to the validation of instance data in the M&S.
data validation rpt	Documentation of the results of performing data validation activities.
data verification results	A statement of the results of the data verification activities for instance data.
design issues	Issues pertaining to the M&S design.
design V&V results	Results of the verification and validation of the new or modified M&S design.
design verification results	Results of performing verification of the new or modified M&S design.
detailed design issues	Issues pertaining to the detailed design.
detailed design/metadata	That part of the M&S design process that allocates functions to specific components/modules/objects of the model or simulation, and its associated documentation (metadata). The detailed design also allocates error budgets to each component of the model or simulation, especially for representational requirements.
entered data/metadata	Instance data and its associated metadata that has been loaded into data sets/databases for use in the M&S.
environmental issues	Concerns specifically addressing the simulated environment in which the M&S scenarios are executed.
environmental planning issues	Environmental (scenario) concerns that specifically impact planning (i.e., application, development, V&V).
formal guidance	Procedures, regulations, guidelines, policies, etc., applicable to all or part of the M&S life cycle, including those pertaining to application, M&S development, M&S modification, testing, model and data V&V, and accreditation.
h-w data issues	Concerns pertaining to hard-wired data and constants used in the M&S.
h-w data rqmts	M&S and/or application requirements for constants and other hard-wired data.
h-w data V&V results	Results of verifying and validating the hard-wired data to be used in the M&S.

impl verification results	Results from the verification of the implementation phase of the development/modification. At a minimum, the results should include an as-built requirements trace matrix.
implementation issues	Issues pertaining to the code.
implementation V&V results	Results of the M&S implementation V&V activities.
implementation validation results	Results of the M&S implementation validation activities.
int ver issues	Questions or concerns raised over the verification of integrated models(s)/simulations.
int ver results	Results of the M&S integration verification effort.
integrated model	Model resulting from the proper assembly of the selected components.
integration issues	Concerns relating to the integration of the M&S components.
integration V&V results	Results of the M&S integration V&V effort.
integration validation results	Results of the M&S integration validation effort.
lessons learned	Document containing significant information about the M&S and the entire life cycle process that is not evident in traditional or standard documentation.
M&S design issues	Issues specifically related to the design of M&S or its components.
M&S development plan	The planning document governing the development or modification of the M&S.
M&S Development Team	Members of the technical staff with responsibility to develop or modify the M&S.
M&S development tools	Tools selected to support the M&S development and/or modification process, such as CASE tools, software development environments, etc.
M&S documentation	Documentation to be archived that describes all aspects of preparing the M&S for use in the specific application, including development, modification, testing, V&V, etc.
M&S HW	The suite of computers, peripheral devices, hardware-in-the-loop devices, simulators, and miscellaneous devices that comprise the equipment necessary to use the M&S.
M&S Management Team	The group responsible for planning and overseeing the entire M&S life cycle.
M&S rqmts	Constraints, limitations, and additional information required for the development or operation of the M&S including data values, properties, formats; hardware and software specifications, etc.

M&S rqmts issues	Questions raised about given or potential M&S requirements during model or data verification or validation.
M&S V&V history	Information identifying past verification and validation activities for all potential models and their instance data sets.
metadata issues	Issues related to the existence, quality, etc., of metadata associated with any kind of data relevant in the M&S life cycle, but particularly associated with M&S instance data.
metadata updates	Additions or changes made to the metadata associated with changes made to the associated model/data.
metadata verification results	Results of checking metadata for completeness and sufficiency.
model application	The model/simulation as prepared for use to support the application, but prior to verification and validation.
model dev/mod request	A request to an outside agency (Sponsor) of a M&S or component to develop or modify it in order to support application requirements for which the M&S is being considered.
model imp issues	Issues pertaining to the code.
model issues	Concerns pertaining to the design, development, or use of a specific component of the M&S.
model mod request	A request to the developer, owner or sponsor to modify a model or component in order to support the application.
model validation issues	Issues specifically related to the validation of the M&S, exclusive of validation of its instance data.
model validation rpt	Documentation of the model validation effort.
model(s)/metadata	The set of model(s), developed or selected, to support the application, together with supporting model description data.
model/data V&V approach	The methods used in the verification and validation process. Should include a list of activities and information requirements needed to address each of the model and data V&V requirements including, the sufficiency and appropriateness of individual databases, types or categories to be used in the application.
model/data V&V issues	Concerns directly pertaining to the verification and validation of a specific component of M&S or its instance data.
model/data V&V process issues	Issues pertaining to the model and/or data V&V process.
model/data V&V rqmts	Combined requirements for M&S, model and/or data V&V for the application.
model/data V&V rqmts issues	Issues pertaining to the model and/or data V&V requirements.

output data	Data produced by the M&S and collected for analysis. The end result of M&S execution. May be used during the validation process.
pedigree issues	Concerns related to the origin, sequence of movement or transformations of data enroute to the M&S it supports.
planning data	Miscellaneous information necessary to effectively plan the development, modification and/or application of M&S for the purpose identified in the problem statement. Includes data needed for planning M&S testing, model/data V&V, and accreditation activities as well.
planning information	Information gleaned from planning data to be used in different planning processes.
potential instance data/metadata	Data and its associated metadata that may be useable to support the M&S during its execution.
potential model(s)/metadata	A set of model(s), including existing models that may be useful and useable in addressing the problem, together with supporting model description data.
potential tools	Tools, techniques, models, etc. identified for possible use during the development, modification, testing, preparation or V&V of the M&S.
preliminary design issues	Issues directly pertaining to the preliminary design of the M&S.
preliminary design/metadata	That part of the M&S design that allocates requirements to components of the M&S in which they are to be implemented and its metadata. The initial identification and documentation of supporting data requirements is a part of preliminary design.
Problem Statement	Articulation of the issue(s) to be addressed through use of the M&S. Also, the trigger to initiate the process.
ready data	Data that have been collected, prepared, transformed, entered, and verified for use in the application. Although some validation activities have occurred, the data validation process will be done in conjunction with model validation (M&S validation).
rejected reviewed data	Data or data sets reviewed for suitability in the M&S application that have been rejected in favor of alternative data or data sets.
rejected transformation methods	Data transformation methods that have been rejected for application in the current M&S in favor of alternative transformation methods.
rejected transformed data	Data or data sets that are rejected for use in the M&S following transformation.

Rqmts Specification	Formal document defining M&S requirements to be satisfied by the Develop/Modify M&S effort.
run request	Trigger to execute the application.
sel. data/metadata to be transformed	Data (and its associated metadata) obtained from an appropriate data source and ready for transformation into a form suitable for use by the M&S.
sel. data/metadata used as-is	Data (and its associated metadata) selected for use in the M&S that does not require transformation to be suitable for use.
sel. h-w data/metadata	Data (and associated metadata) selected for use as constants (hard-wired) in the M&S.
selected data/metadata	Instance data (and its associated metadata) obtained from an appropriate data source that has been selected for use in the M&S.
selected model(s)/history	Models/simulations or components selected for use in the application together with documentation of their development, verification, validation, and prior use.
SME	Subject Matter Experts. People who are experts in a specific area, in particular, experts in the model domain with sufficient knowledge to evaluate M&S and/or data usage.
sponsor rqmts	Requirements established for the M&S component of the application.
tool enhancement request	Request for modification of a tool or technique being considered for use in M&S development or modification, data preparation or transformation, testing, model or data V&V, or accreditation.
tool issues	Questions raised about the appropriateness or sufficiency of tools being used in M&S development or modification, data preparation or transformation, testing, model or data V&V, or accreditation.
transformed data not verifiable	Data selected for use (both instance and hard-wired) that have been transformed but could not be verified following the transformation.
transformed h-w data/metadata	Data that have been transformed suitably for use as hard-wired (constants) in the M&S, together with the metadata documenting relevant facts about the transformation.
transformed instance data/metadata	Instance data transformed for use by a specific M&S, together with the metadata documenting relevant facts about the transformation.

V&V Agent	The individual/organization responsible to the Accreditation Authority for performing all M&S and instance data V&V activities and for supporting accreditation activities.
V&V plans	Detailed plans for verification and validation of the models and data involved in the current M&S application. Developed in conjunction with accreditation, and M&S development or modification plans for same.
V&V preliminary design results	Results of the preliminary design V&V effort.
V&V Report	Documentation of the methods used and results of performing verification and validation on the M&S and its model and data components.
V&V rqmts issues	Issues pertaining to the requirements for V&V of the M&S, models and/or data for the specified application.
V&V tool choices	Tools chosen to apply to the verification and validation of the M&S. Becomes a subset of “analysis tools and methods.”
V&V’d conceptual model	The conceptual model (and its associated metadata) following acceptance (by the M&S Management Team) of the verification and validation results.
V&V’d detailed design/metadata	The detailed design (and its associated metadata) following acceptance (by the M&S Management Team) of the verification and validation results.
V&V’d h-w data/metadata	The constants (and associated metadata) following acceptance (by the M&S Management Team) of the verification and validation results.
V&V’d application/metadata	The M&S application (and its associated metadata) following acceptance (by the M&S Management Team) of the verification and validation results.
V&V’d implemented model(s)/metadata	The code (implementation) and its associated metadata following acceptance (by the M&S Management Team) of the verification and validation results.
V&V’d integrated model(s)/metadata	The integrated model (and its associated metadata) following acceptance (by the M&S Management Team) of the verification and validation results.
V&V’d preliminary design/metadata	The preliminary design (and its associated metadata) following acceptance (by the M&S Management Team) of the verification and validation results.
validated data	Data that have been determined valid (or valid with exceptions) (accepted by the M&S Management Team) for use in the M&S for the current application or application class.

validated model(s)	Models and/or simulations that have been determined valid (or valid with exceptions) (i.e., accepted by the M&S Management Team) for the current M&S application or application class.
verification issues	Questions and concerns related to verification activities of models and/or data.
verification rpt	Documentation of the model and/or data verification activity.
verified entered data/metadata	The entered data (and associated metadata) following acceptance (by the M&S Management Team) of the verification results.
verified transformed data/metadata	The transformed data (and associated metadata) following acceptance (by the M&S Management Team) of the verification results.
VV&A request	The trigger for the VV&A process.

ACTIVITY – ICOM MAP FOR EXECUTE M&S LIFE CYCLE PROCESS

Activity Name	Inputs	Controls	Outputs	Mechanisms
EXECUTE M&S LIFE CYCLE PROCESS	Problem Statement	formal guidance	Rqmts Specification	M&S Management Team
	potential instance data/metadata planning data potential model(s)/metadata potential tools M&S V&V history candidate h-w data/metadata run request	ADS data stds available resources sponsor rqmts application plan	M&S development plan V&V plans accreditation plan M&S rqmts data rqmts add'l model info request data mod request add'l data/metadata request tool enhancement request lessons learned accredited application M&S documentation V&V Report Accreditation Report archived data	M&S Development Team Data Producer V&V Agent M&S HW Accreditation Authority SME
Initiate Application	Problem Statement	formal guidance	data rqmts	Accreditation Authority
	potential instance data/metadata planning data potential tools M&S V&V history potential model(s)/metadata add'l model/data V&V request environmental issues accreditation process issues add'l model/data request data rqmt issues	ADS data stds application plan available resources sponsor rqmts	M&S rqmts accreditation plan M&S development plan add'l model info request tool enhancement request selected model(s)/history add'l data/metadata request V&V plans Rqmts Specification data mod request	Data Producer M&S Management Team V&V Agent

Activity Name	Inputs	Controls	Outputs	Mechanisms
Identify M&S Rqmts	model/data V&V process issues data prep tools M&S rqmts issues Problem Statement	formal guidance	model dev/mod request model issues analysis tools & methods M&S development tools M&S rqmts	M&S Management Team Accreditation Authority
Formulate Plans	potential model(s)/metadata M&S V&V history potential instance data/metadata M&S rqmts issues add'l model/data request environmental issues candidate model(s) candidate data accreditation process issues planning data potential tools M&S V&V history environmental issues model/data V&V process issues data prep tools add'l model/data V&V request environmental planning issues	application plan available resources data stds M&S rqmts data rqmts available resources formal guidance data stds application plan ADS sponsor rqmts	model dev/mod request data rqmt issues candidate model(s) candidate data M&S development plan model issues V&V plans accreditation plan data rqmt issues selected model(s)/history tool enhancement request analysis tools & methods M&S development tools add'l data/metadata request add'l model info request environmental issues acceptability criteria M&S rqmts issues data issues	M&S Management Team Accreditation Authority V&V Agent M&S Management Team Accreditation Authority V&V Agent
Collect Planning Information	planning data environmental issues	formal guidance ADS	add'l data/metadata request tool enhancement request	M&S Management Team

Activity Name	Inputs	Controls	Outputs	Mechanisms
Develop M&S Plan	candidate model(s)	data rqmts	add'l model info request	M&S Management Team
	environmental planning issues	M&S rqmts	selected model(s)/history	
	candidate data	sponsor rqmts	planning information	
	potential tools	available resources	candidate M&S tools	
	M&S V&V history	application plan		
	data prep tools			
	selected model(s)/history	formal guidance	add'l data/metadata request	
	planning information	ADS	tool enhancement request	
	candidate M&S tools	data rqmts	add'l model info request	
	candidate data	M&S rqmts	M&S development plan	
Develop VV&A Plans		sponsor rqmts	M&S development tools	M&S Management Team Accreditation Authority V&V Agent
		available resources	analysis tools & methods	
		application plan	VV&A request	
	VV&A request	M&S development tools	add'l data/metadata request	
	selected model(s)/history	M&S development plan	tool enhancement request	
	planning information	formal guidance	analysis tools & methods	
	M&S V&V history	ADS	model issues	
	potential tools	data rqmts	data rqmt issues	
	candidate data	M&S rqmts	environmental issues	
	environmental planning issues	sponsor rqmts	data issues	
Identify VVA Rqmts	data prep tools	available resources	M&S rqmts issues	M&S Management Team V&V Agent Accreditation Authority
	add'l model/data V&V request	application plan	V&V plans	
	accreditation process issues	data stds	accreditation plan	
	model/data V&V process issues		acceptability criteria	
	VV&A request	ADS	environmental issues	
	selected model(s)/history	sponsor rqmts	model issues	
	environmental planning issues	formal guidance	data issues	
	candidate data	M&S rqmts	add'l data/metadata request	

Activity Name	Inputs	Controls	Outputs	Mechanisms
Review M&S Rqmts	add'l model/data V&V request M&S V&V history model/data V&V rqmts issues environmental planning issues VV&A request selected model(s)/history add'l model/data V&V request M&S V&V history	data rqmts available resources data stds M&S development plan application plan M&S development plan M&S rqmts data rqmts sponsor rqmts application plan available resources	data rqmt issues M&S rqmts issues acceptability criteria model/data V&V rqmts environmental issues model issues M&S rqmts issues V&V rqmts issues data issues data V&V rqmts issues acceptability criteria issues	M&S Management Team V&V Agent
Determine Acceptability Criteria	acceptability criteria issues	M&S development plan available resources M&S rqmts formal guidance application plan available resources	M&S rqmts issues acceptability criteria V&V rqmts issues data V&V rqmts issues M&S rqmts issues	V&V Agent Accreditation Authority
Determine Model V&V Rqmts	acceptability criteria V&V rqmts issues M&S V&V history model/data V&V rqmts issues	M&S development plan formal guidance M&S rqmts application plan available resources	model/data V&V rqmts data V&V rqmts issues acceptability criteria issues M&S rqmts issues	V&V Agent
Determine Data V&V Rqmts	data issues data V&V rqmts issues candidate data acceptability criteria	application plan available resources M&S development plan formal guidance M&S rqmts data rqmts application plan	environmental issues M&S rqmts issues data issues model/data V&V rqmts data rqmt issues add'l data/metadata request	V&V Agent

Activity Name	Inputs	Controls	Outputs	Mechanisms
Select VVA Tools & Techniques	acceptability criteria model/data V&V rqmts potential tools data prep tools tool issues	data stds ADS data rqmts M&S development plan application plan M&S rqmts M&S development tools available resources	acceptability criteria issues V&V rqmts issues add'l data/metadata request tool enhancement request accreditation approach analysis tools & methods model/data V&V approach V&V tool choices accreditation tool choices	Accreditation Authority V&V Agent M&S Management Team
Determine Accreditation Assessment Approach	acceptability criteria accreditation tool choices model/data V&V approach	application plan M&S rqmts M&S development plan M&S development tools	accreditation approach tool issues	Accreditation Authority V&V Agent M&S Management Team
Determine V&V Approach	accreditation approach model/data V&V rqmts V&V tool choices	M&S development tools M&S development plan M&S rqmts application plan data rqmts available resources	add'l data/metadata request model/data V&V approach tool issues	V&V Agent
Select VVA Tools & Models	M&S development tools model/data V&V approach potential tools accreditation approach tool issues data prep tools	M&S development plan M&S rqmts available resources application plan	tool enhancement request analysis tools & methods accreditation tool choices V&V tool choices	V&V Agent Accreditation Authority
Develop Model/Data V&V Plans	acceptability criteria analysis tools & methods	available resources data rqmts	add'l data/metadata request V&V plans	V&V Agent

Activity Name	Inputs	Controls	Outputs	Mechanisms
Develop Accreditation Plan	model/data V&V approach	sponsor rqmts	accreditation issues	Accreditation Authority V&V Agent
	V&V tool choices	M&S rqmts	tool issues	
	model/data V&V process issues	formal guidance	model/data V&V rqmts issues	
	M&S V&V history	application plan		
	model/data V&V rqmts	data stds		
	planning information	M&S development plan		
	candidate data			
	accreditation plan			
	selected model(s)/history			
	model/data V&V issues			
	acceptability criteria	available resources	add'l data/metadata request	
	accreditation approach	M&S development plan	accreditation plan	
	V&V plans	sponsor rqmts	tool issues	
	accreditation issues	application plan	model/data V&V issues	
	analysis tools & methods	M&S rqmts		
	model/data V&V rqmts	formal guidance		
	selected model(s)/history			
	accreditation process issues			
	accreditation tool choices			
	planning information			

Appendix F

Recommendations for Changes to the *VV&A RPG*

The principal objective of the VV&C Tiger Team was to develop a common technical foundation for data user V&V. It was felt that the team's results would provide information that is both essential and supportive in understanding, guiding, and implementing common data V&V activities. The information would enable each DoD Component to prepare tailored policies and implementation action plans. In support of this objective, the Tiger Team was to produce recommended changes to the *VV&A Recommended Practices Guide* (RPG).

The recommendations for changes to the *VV&A Recommended Practices Guide* were made with the understanding that the Defense Modeling and Simulation Office (DMSO) is implementing a substantial revision and enhancement of the present document. References to the November 1996 version of the RPG are provided in parentheses within this appendix to assist those performing the rewrite.

User data V&V processes should be integrated into the RPG's V&V and Accreditation discussion to such an extent that it will be difficult to overlook user data V&V or give it insufficient attention (especially 1.1 and 1.4). In short, it should be impossible to do model V&V without doing user data V&V, or to do either separately. In addition, data should not be addressed separately in any part of the RPG as this could enforce the misperception that data issues are separate from modeling and V&V and Accreditation issues.

As mentioned previously, the Tiger Team concluded that there is no need for a discrete data certification activity or step as long as accreditation encompasses the understanding that V&V has included data. If this recommendation is accepted, care should be taken to avoid any reference to certification as a process or product in the text and diagrams. Also as outlined previously, by making user data V&V an integral part of M&S V&V and Accreditation, the acronym "VV&C" can be eliminated completely from the RPG.

The role of data in M&S life cycle and how data is to be handled should be addressed. More specifically, any discussion of verification (1.2.2) and validation (1.2.3) needs to be augmented with points about data V&V (also 1.3.7). Such a discussion should follow the Updated M&S Life Cycle Process Model presented in Appendix E of the White Paper. Also, the text should emphasize the validation of data within the context of the model's intended use. It is equally important to clarify the concept of user data V&V, especially as it relates to V&V and Accreditation (1.5). All of the above should emphasize that data credibility underlies confidence in M&S (1.3.1). The idea that understanding the pedigree of data is essential for confident reuse, etc. should be enforced (1.3.3). Likewise, the idea that improved analysis is also dependent on knowledge of data pedigree should appear (1.3.5). The ideas contained in the previous three sentences should appear much earlier in the document than the sections noted. The paradigm of data producer and data user, and the relationship between them, should also be presented in an introductory section and then carried on throughout the RPG.

In terms of practical considerations (1.6) a discussion of the risk engendered by ignoring validation and verification issues, including those related to user data V&V, should be included. This should be reinforced with real examples showing the benefits of performing V&V and the potential consequences of not performing it, or not performing it properly. This also should include a subsection about documenting data sources, tracking transformations, etc. (1.6.1.?). A discussion of data pedigree tracking in configuration management should appear (1.6.2).

Text specifically addressing the key concepts of V&V and Accreditation (e.g., Chapter 5) should occur at an early point in the document. This serves to emphasize the desired end results before delving into detail with processes and techniques.

The concepts of user data V&V need to be integrated throughout any general discussion of principles (Chapter 2). To add emphasis to this, it is recommended that principles addressing user data V&V and its role in V&V and Accreditation (2.12) be placed near the front of such a discussion. Other than these measures, data should not be addressed separately, for the reasons already explained.

Discussion of M&S validity should address issues of data resolution and similar consideration (2.1). When addressing M&S credibility with respect to intended use (2.4) it is important that the use of data appropriate for the application be included.

In text detailing V&V and Accreditation processes (Chapter 3), it is essential to include the results of the Updated M&S Life Cycle Process Model and the Data DQ Metadata Template presented in this report (Appendices E and D, respectively) – at least in some form. This would illustrate the processes in detail, allowing practitioners to identify essential elements for their program(s) and to take measures necessary to ensure that these elements are addressed.

Techniques more applicable to user data V&V need to be added to the RPG (Chapter 4). In addition, the Tiger Team felt that the existing text needs more explanation of the objectives of techniques, how the techniques are to be used, and how one makes a choice of the best technique(s) for particular applications. An explanation of how techniques are applied in combination, especially for concurrent data and model V&V, should also be added.

Text addressing common reporting formats (Chapter 6) needs to be revised to insert user data V&V. This would, again, help to ensure that data is given proper attention as an integrated element of V&V and Accreditation.

The Tiger Team felt that a new chapter or an appendix should be added to capture lessons learned from practical V&V and Accreditation experience. This would naturally include data issues.

User data V&V should be included as integrated elements in any process or flow diagrams (such as Fig. 1-1, section 1.4).

All lists of references should be augmented with helpful additional sources addressing data issues, practices, etc. (Chapter 2 especially).

Appendix G

General Recommendations for Changes to V&V and Accreditation Policy/Guidance

The principal objective of the VV&C Tiger Team was to develop a common technical foundation for data user V&V. It was felt that the team's results would provide information that is both essential and supportive in understanding, guiding, and implementing common data V&V activities. The information, collected in this appendix, would enable each DoD Component to prepare tailored policies and implementation action plans.

Any guidance or policy should emphasize that the credibility of constituent data underlies the confidence in any models and simulations. This confidence rests upon the intended use of the M&S and, in turn, upon use of appropriate data for that application. Data should be validated within the context of the model's intended use. So, there is risk engendered by ignoring V&V of component data in the M&S V&V and Accreditation.

The Tiger Team had great concern with the fact that data V&V and Certification at the user level is currently perceived as a function that is separate from the functions associated with V&V and Accreditation of M&S. Put another way, there is a misperception that data issues are separate from modeling and V&V and Accreditation issues. Consistent with these observations, what are presently considered V&V and Certification activities should be integrated into V&V and Accreditation to such an extent that it will be difficult to overlook user data V&V or give it insufficient attention. In short, it should be impossible to do model V&V without doing user data V&V, or to do either separately. The Updated M&S Life Cycle Process Model presented in Appendix E of the White Paper can be used as a guide for integrating these activities.

The Tiger Team felt that there is no requirement for a discrete user data certification activity or step as long as accreditation encompasses the understanding that V&V of the M&S has included user data V&V.

Understanding the pedigree of data is also essential for credible reuse. Likewise, improved analysis is also dependent on knowledge of data pedigree. Both the data producer and the data user have a role to play in ensuring complete data pedigree documentation.

The current use of the conglomerate phrase "V&V of data" is problematic. Data V&V and Certification activities are divided between those data quality activities carried out by the producer and user data V&V activities associated with a model and/or simulation. However, by making user data V&V an integral part of M&S V&V and Accreditation, the acronym "VV&C" can be eliminated completely from the M&S vernacular.